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Aspects de la diffusion des connaissances motivées par des problèmes de sécurité et des défaillances technologiques

Responsable administratif :
Nicolas Curien, Directeur du laboratoire d'économétrie, CNAM, Paris.

Responsable scientifique :
Dominique Foray, Directeur de recherche, CNRS, Paris.

Coordinatrice :
Emmanuelle Fauchart, Laboratoire d'économétrie, CNAM, Paris.

Contributeurs :
Robin Cowan, MERIT, Maastricht, Netherlands.
Emmanuelle Fauchart, Laboratoire d'Econométrie, CNAM, Paris.
Philip Gunby, University of Canterbury, New Zealand.
Goeffrey Rothwell, Departement of Economics, Stanford University, USA.

Laboratoire d'économétrie,
Conservatoire national des arts et métiers
2 rue Conté, 75003 Paris

Présentation des contributions

Ce rapport se présente sous forme d'une série de contributions ayant pour thème commun les enjeux économiques de la diffusion des connaissances motivées par des défaillances technologiques (généralement à l'origine de désastres ou incidents) et des problèmes de sécurité.

Un premier rapport, dans le cadre du programme « Risques et situations de crise » du CNRS, avait porté sur le concept d'apprentissage par les désastres. Nous avions défini l'apprentissage par les désastres et incidents comme une forme d'apprentissage par la pratique (« *learning by doing* ») et en avions tiré les conséquences en matière de contrainte sur la production de connaissances suite à un incident ou désastre. Ce rapport EPR est un prolongement de cette première réflexion et propose un ensemble de contributions sur le thème de la diffusion des connaissances motivées par des défaillances technologiques, des désastres, des problèmes de sécurité. Plus particulièrement, ces contributions s'inscrivent dans les thématiques générales suivantes :

- Etant donné l'importance des communications entre individus ayant des informations dispersées sur un problème technologique aux conséquences potentiellement graves, existe t-il une structure de communication plus efficace que les autres pour assurer la bonne circulation de ces informations ?
- Quelles sont les caractéristiques temporelle, géographique, et professionnelle de la diffusion des informations et connaissances sur un désastre technologique ? La diffusion est-elle large ou plutôt restreinte ? Cela dépend t-il des mécanismes de diffusion ?
- Quel est le comportement des firmes privées en matière d'échange de connaissances et d'information sur la sécurité ? S'échangent-elles leurs informations, partagent-elles leurs expériences, ou au contraire ont-elles un comportement individualiste ? Y a t-il des connaissances sécurité qu'elles partagent et d'autres qu'elles gardent privées, et si oui quel est le critère de discrimination ?
- Quels sont les rôles respectifs de la standardisation et de la diversité technologiques en matière de sécurité technologique et qu'en déduire quant à la rationalité souhaitable des choix technologiques en présence de risques ?

Structure de communication assurant la meilleure diffusion des informations

La première contribution utilise la théorie des réseaux pour montrer la structure que doivent avoir les réseaux de communication entre individus pour assurer la diffusion la plus efficace des informations ou connaissances portant sur une défaillance technologique quand celles-ci sont dispersées.

Une partie significative des incidents technologiques graves est due à des défaillances de technologies utilisées par de multiples usagers, dispersés géographiquement, situés parfois dans des industries différentes, et généralement non connectés entre eux. Ce type d'incidents graves ou de désastres est certainement amené à se développer, en raison de l'usage croissant des technologies dans tous les secteurs de l'activité économique. Le désastre « Therac-25 » (voir Cowan, Fauchart, Foray, Gunby, « *Learning from disaster* », 2002, working paper) est un exemple connu de désastre du à une défaillance de logiciel dans une machine de traitement du cancer par radiation. Ce désastre a consisté en une série d'incidents, ayant eu lieu dans des institutions médicales, dispersées géographiquement, et non connectées entre elles. La dispersion des informations sur l'occurrence d'incidents et sur l'origine possible de ces incidents ainsi que l'absence d'agglomération d'information permettant de repérer une tendance a considérablement retardé l'apprentissage et la mise en place d'actions correctrices. Ce cas, et la croissance prévisible du nombre de désastres comparables dans les prochaines décennies, nous a amené à considérer l'importance des structures de communication pour l'occurrence et la rapidité de l'apprentissage par les incidents.

La question est alors d'étudier les propriétés de la meilleure structure de communication possible, c'est-à-dire la structure qui :

- permet aux individus de recevoir une quantité d'information qui ne soit ni trop faible ni trop grande. Si chaque individu recevait systématiquement toutes les informations produites dans son industrie, il serait submergé, et sa capacité à repérer les informations pertinentes pour lui serait altérée. A l'inverse, une rétention totale d'information ne permet pas aux individus de prendre connaissance des informations pertinentes, telles que l'occurrence d'un incident avec une technologie similaire à celle qu'il utilise.
- Permet aux individus de se communiquer des connaissances tacites ou faiblement articulées. Toute connaissance articulée peut se transmettre dans un format facilement diffusable et diffusable à faible coût. En revanche, les connaissances non articulées doivent généralement être communiquées directement. Par exemple, les techniciens hospitaliers qui ont fait l'expérience d'un incident avec la machine Therac-25 ont typiquement communiqué le déroulement de l'expérience de façon orale et directe, déroulant les différents scénarios possibles, discutant des origines possibles de l'incident, se remémorant les différentes opérations qu'ils avaient effectuées. De plus, l'apprentissage n'a pu avoir lieu que quand toute l'information a été agglomérée, que les utilisateurs se sont rencontrés directement pour comprendre le problème. En comparant leurs expériences et en agrégeant leurs connaissances et informations, ils ont pu comprendre l'origine de la défaillance.

La contribution montre que la meilleure structure possible, étant donné les objectifs fixés, est celle du « petit monde », une structure de communication caractérisée par des « chemins courts » reliant entre elles des « cliques ». Une clique est un petit ensemble (comparé à la taille totale du réseau) d'individus (ou d'entités : firmes, agents..) très connectés entre eux, mais peu connectés avec l'extérieur. La structure du petit monde cependant relie les cliques entre elles par des chemins courts, c'est-à-dire directs – de clique à clique. Les bonnes propriétés de cette structure s'expliquent facilement :

- les individus ont des liens directs avec un petit ensemble cohérent d'individus, qu'on appelle une clique.
- Les individus sont reliés au monde extérieur et profitent d'informations pertinentes produites en dehors de leur cercle restreint de connections intenses sans cependant être submergés d'informations. En fait les informations reçues de l'extérieur sont « triées » par les autres cliques, qui ont sélectionnées les informations produites par elles et qu'elles estiment pertinentes pour chaque autre clique.

La structure du petit monde permet ainsi de profiter de « chemin courts » - propice à la diffusion rapide des informations – et de fortes connections « locales » - propice à la transmission des connaissances peu articulées.

En conclusion, les implications concrètes des résultats théoriques sont exposées. En particulier, il est suggéré que développer la communication entre utilisateurs de technologies similaires ou proches est nécessaire à un apprentissage par les incidents et désastres plus efficace. Dans la réalité, cette communication est généralement inexistante. Quand des structures existent, telles que celles mises en place par les associations d'industries ou les instances de régulation, elles reposent rarement sur une structure de petit monde.

Propriétés de la diffusion des informations sur un désastre

La seconde contribution est une étude très détaillée des propriétés de la diffusion des connaissances produites par un désastre : diffusion dans le temps, diffusion dans l'espace, diffusion inter-industrielle. Le désastre est le cas Therac-25, que nous avons déjà évoqué. Ce « désastre » - plusieurs patients sont morts par irradiation due à une défaillance du logiciel commandant le dosage à administrer par la machine – est un désastre qui a reçu une certaine publicité en Amérique du Nord. Plusieurs familles de patients ont attaqué le fabricant et les institutions hospitalières concernées en justice. La presse s'est fait le relais de ces procès. L'instance de régulation du secteur médical aux Etats-Unis, la Food and drug Administration (FDA), a modifié sa législation en 1990 avec le Safe Medical Device Act (SMDA), en partie pour accroître son pouvoir de contrôle sur les machines médicales contrôlées par ordinateur dans la suite du cas Therac-25. La FDA a également supervisé les modifications de la machine dans la période suivant les incidents. Enfin, étant un des premiers procès d'une machine contrôlée par ordinateur ayant causé des morts civiles, de surcroît par irradiation, les experts en informatique convoqués aux procès ont également publié des articles très documentés sur le cas Therac-25. Plus généralement, un certain nombre d'apprentissages ont été motivés par le cas Therac-25. La question est donc alors de savoir si ces apprentissages se sont diffusés.

Pour étudier la diffusion des apprentissages motivés par le désastre Therac-25 (voir également, Cowan *et al.* 2002 pour une synthèse de ces apprentissages), dans ses diverses dimensions (temporelle, géographique, industrielle), nous avons élaboré une méthodologie consistant à construire des statistiques sur les citations du cas Therac-25. Notre hypothèse est donc qu'une façon pertinente et rigoureuse, car se prêtant à l'analyse statistique, de repérer la diffusion des apprentissages motivés par la défaillance de la machine Therac-25 est d'établir la trace dans le temps et dans l'espace (géographique et industriel) des références au nom « Therac-25 » (et autres mots pertinents susceptibles d'être liés à ces références, pour les cas où le nom même de la machine ne serait pas mentionné directement). Il ne s'agit donc pas d'établir quels apprentissages se sont diffusés, par quel mécanismes *etc*… qui serait un travail titanesque, mais de proposer une méthodologie, reproductible, de traçage des références à un désastre ou incident majeur particulier et d'en tirer des résultats quant aux propriétés de la diffusion (locale/globale…).

Face à la multitude des sources susceptibles de se référer au cas Therac-25 (conférences, documents administratifs, documents d'entreprise, journaux *etc*…), nous avons choisi d'étudier statistiquement :

- les citations systématiques du cas Therac-25 dans les 66 « newsgroups » accessibles sur Internet les plus pertinents (comp.risks, comp.software-eng, …) pour notre étude, à savoir les forums de discussions en informatique, logiciel, secteur médical, ingénierie. Les newsgroups sont des forums de discussion où les professionnels ou experts échangent des idées, des informations, des opinions. Nos statistiques portent sur la période 1985-2003, 1985 étant l'année des premiers incidents. Pour repérer les citations du cas, plusieurs mots clés ont été utilisés (non seulement « Therac-25 » mais également « radiation », « AECL » (nom du fabricant) par exemple, au cas où l'article posté sur le site traiterait du cas sans citer le nom de la machine). Le travail statistique consiste à repérer tous les articles « postés » sur les sites par date, par type de site (logiciel, médical…), par affiliation (académique, gouvernemental, entreprise) des envoyeurs de messages ou articles ;
- les citations du livre de Nancy Leveson « *Safeware : System Safety and Computers* » datant de 1995. Nancy Leveson, professeure d'informatique au MIT (Massachussets Institute of Technology, Cambridge, USA) est une des meilleures expertes mondiales sur les questions de sécurité et fiabilité des systèmes informatiques. Elle fut experte

appelée à l'un des procès du cas Therac-25. Elle a ainsi eu accès à l'information détaillée sur les incidents, leurs causes, le fonctionnement de la machine, et son programme logiciel notamment. Son livre de 1995 est une source primaire sur le cas Therac-25 : toute personne lisant le livre en entier connaît l'épisode Therac-25 et les leçons qui en ont été tirées. Le travail statistique consiste à repérer qui cite cet ouvrage par affiliation des auteurs citant, par origine géographique des auteurs citant, par origine professionnelle des auteurs citant.

Le premier groupe de sources – les newsgroups – fournit un traçage des flux informels d'information et de connaissances sur le désastre Therac-25 tandis que la seconde source – le livre de Nancy Leveson – fournit un traçage des flux formels.

Le traitement statistique montre que les caractéristiques de la diffusion sont significativement différentes en ce qui concerne les newsgroups et le livre de Nancy Leveson. En particulier :

- l'origine géographique des citations est beaucoup plus restreinte en ce qui concerne les newsgroups que les citations du livre de Nancy Leveson. Autrement dit, les flux informels sont beaucoup plus localisés géographiquement que les flux formels (les flux informels se sont presque entièrement limités à l'Amérique du Nord) ;
- les flux informels ont eu lieu principalement entre spécialistes du logiciel et de l'informatique alors que les flux formels ont eu une étendue plus large (approximativement 60% dans le domaine du logiciel et de l'informatique, mais près de 30% dans l'ingénierie non directement liée à l'informatique, et un peu dans le secteur médical, notamment sur l'aspect éthique) ;
- une large majorité des flux formels ont lieu entre académiques (75%) alors que la majorité des flux informels ont lieu entre employés d'entreprises commerciales (61%) ;
- le profil temporel des flux informels est moins marqué que celui des flux formels.

Nous trouvons ces résultats très encourageants. Le travail statistique a permis de repérer des tendances significatives et des différences significatives entre flux d'information informels et formels. Les pistes ouvertes, pour continuer ce travail, sont nombreuses. On pourrait étudier d'autres sources d'informations (par exemple l'article de Nancy Leveson dans *Computer* en 1993), d'autres mécanismes de diffusion (communications dans des conférences, citation dans des documents d'associations d'industries ou professionnels (tel l'ACM..), d'administration, d'instances de régulation.

Rationalité des échanges de connaissances sur la sécurité entre firmes

La troisième contribution est une étude des échanges d'information sur la sécurité entre firmes privées. Il existe des études sur le retour d'expérience dans le nucléaire et autres secteurs dominés par les firmes publiques, mais presque aucune sur les secteurs dominés par les firmes privées. L'étude de cas porte sur l'industrie européenne du chlore. Il s'agit d'une industrie à risque et, par conséquent, régulée.

Notre étude montre que certaines informations sécurité sont échangées et d'autres non. Les firmes n'échangent pas d'informations sécurité lorsque celles-ci sont liées au processus d'électrolyse. En revanche, elles échangent intensément sur les problèmes de sécurité liés au stockage et au transport du chlore. Comment expliquer ce résultat ? Le stockage et le transport du chlore sont régulés car il s'agit d'une substance à risque. Les firmes s'entendent généralement pour avoir une position commune sur les aspects régulés, mais ceci n'est pas suffisant pour en déduire la profondeur des échanges. Un aspect important est que tout accident survenant dans une situation de stockage ou de transport est généralement visible et porteur de fortes conséquences, allant d'un renforcement de la législation à une potentielle interdiction de transport du chlore. Ainsi, un accident dans une usine implique potentiellement des coûts et risques économiques pour toutes les usines et firmes du secteur. Le processus d'électrolyse en revanche n'est pas associé aux mêmes risques économiques. Des incidents peuvent se produire mais ils sont peu dangereux et surtout peu visibles. Leurs conséquences économiques sont donc faibles.

De cette étude empirique nous en déduisons que la constatation pertinente est la suivante : toute information sécurité que les firmes choisissent de ne pas échanger reste compétitive tandis que toute information sécurité que les firmes choisissent d'échanger cesse d'être compétitive. Il devient alors important de comprendre pourquoi les firmes choisissent de garder certaines informations sécurité privées tandis que d'autres sont échangées. Notre argument est que les firmes échangent des informations sécurité lorsque, de façon triviale, les avantages de l'échange sont supérieurs aux avantages de garder l'information privée. Et inversement, elles gardent l'information privée lorsque les avantages de garder l'information sont supérieurs aux avantages de l'échanger. Cet argument s'illustre avec les constatations pour le secteur du chlore. Les firmes échangent sur le stockage et le transport du chlore parce que les bénéfices individuels obtenus de l'échange sont supérieurs à ceux qui seraient obtenus en n'échangeant pas. Ne pas échanger impliquerait que les firmes n'échangeraient pas sur les bonnes pratiques en matière de sécurité relative au stockage et au transport et qu'ainsi les informations de valeur relatives à comment rendre sûres les opérations de stockage et de transport ne circuleraient pas, en particulier entre les grandes firmes et les petites firmes ou entre les entreprises les plus sûres et les moins sûres. En échangeant, les firmes qui ont des informations « utiles » s'assurent que les autres les utilisent pour réduire la probabilité d'accident majeur et par là même pour réduire les menaces sur leur propre activité économique. Il y a clairement plus de bénéfices à attendre à divulguer ces informations qu'à les conserver privées. Les conserver privées maintiendrait ou renforcerait la différence de sécurité et ferait peser sur les firmes les plus sûres le risque d'incident dans les firmes les moins sûres.

A l'inverse, les informations sécurité concernant le processus d'électrolyse ont plus de valeur pour la firme lorsqu'elles sont conservées privées que lorsqu'elles sont divulguées et partagées. D'une part, une mauvaise connaissance du matériel et de la technologie d'électrolyse implique des rendements moins bons et de plus grands risques d'incidents. D'autre part, ces incidents ne sont jamais graves et sont peu visibles, et n'infligent donc pas de coût ou de risque économique aux concurrents. Il n'y aurait donc aucun avantage privé pour les firmes possédant des informations utiles à les partager avec les autres et même le fait de ne pas les partager permet de conserver ou d'accroître ses avantages compétitifs.

L'implication de ce travail est que le fait de partager ou de ne pas partager l'information sécurité n'est pas lié à la nature intrinsèque de l'information et peut donc être modifié en agissant sur les coûts et bénéfices privés de l'échange.

Risque de défaillance et choix technologique

La quatrième contribution est une évaluation théorique du poids du risque de défaillance (technologique) dans les choix technologiques. Un certain nombre de choix technologiques sont effectués par des instances centrales (administration, agence gouvernementale…), qui doivent décider quelle(s) technologie(s) adopter ou imposer. Une dimension importante de la décision est le choix d'un niveau de standardisation technologique : autrement dit, vaut-il mieux choisir (ou développer) une seule technologie ou plusieurs ? Chaque solution comporte des avantages et des inconvénients. Développer plusieurs technologies permet de choisir éventuellement la meilleure, celle qui est la plus économique tout en assurant un bon niveau de sécurité ; en développant plusieurs technologies, on évite aussi de se « retrouver » avec une technologie contenant une défaillance majeure. Toutefois, développer plusieurs technologies a

un coût élevé, celui d'amener à un niveau suffisant de développement plusieurs technologies. De ce point de vue, la standardisation parfaite – ne développer qu'une seule technologie – présente beaucoup d'avantages du point de vue des coûts et de l'apprentissage : (1) on peut réaliser des économies d'échelle dans la production de la technologie ; (2) on réalise également des économies en raison de l' « apprentissage par l'usage » (learning by using), maximisé dans le cas où les unités sont similaires. Notamment, du point de vue de la sécurité, la standardisation maximise l'effet des améliorations de design : toute amélioration est apportée immédiatement à toutes les unités. La standardisation toutefois présente le risque de se trouver avec une technologie défaillante, et sans alternative.
Cette contribution propose un modèle formalisé permettant de calculer le nombre optimal de technologies à développer en fonction de l'étendue respective des économies d'échelle et des économies d'usage, ainsi qu'en fonction de la probabilité d'une défaillance technologique majeure. Le modèle montre qu'étant donné les valeurs crédibles de ces divers paramètres – estimés à partir de données sur les centrales nucléaires – le choix de la standardisation immédiate – ne développer qu'une seule technologie – est toujours le meilleur. Autrement dit, la probabilité d'une défaillance technologique majeure n'est jamais assez élevée pour perdre le bénéfice de la maximisation des économies d'échelle et d'usage. Des modifications possibles du modèle sont exposées en conclusion.

Chapter 1

A Model of Knowledge Creation and Diffusion, with Application to Learning from Disaster

I.1 Introduction

It will never be possible to eliminate technological disasters. It is in the nature of technical progress that accidents will happen. Most of them will be insignificant, but from time to time there will be major ones. While it is true, that by definition a disaster has a large cost, either financial, physical or in human life, it is also the case that a disaster represents an opportunity. It is an unusual event, and as such is a unique learning opportunity. The obvious question is how to capitalize on this opportunity, and to learn as much as possible from it.

In recent years interest in learning and innovation has seen a revival in economics, and the new view of learning can be of use, when thinking about learning from disaster. Several of the insights which have been emphasized in this literature bare directly in how a disaster can be turned to a learning opportunity.

To begin, however, it is worth stressing that there are three kinds of learning the follow a disaster. First, and most immediate, is the learning involved in "recovery". That is, a disaster will typically have immediate consequences. It will produce a state of the world which it is relatively uncommon to observe. Further, it is not a state of the world that we wish to perpetuate. (if it were, we would not call the event a disaster.) Hence, the first item on the learning agenda is how to exit this state to a better one. How to recover from the disaster---what treatment should the victims of Bhopal receive? What should be done with the Union Carbide plant wherein the chemical spill originated? How should we rescue workers from the mine? The second type of learning is more like repair. It involves addressing the technological that caused the disaster, and, hopefully, finding ways to ensure it does not re-occur. Why did the Challenger explode? Why was it necessary to abort the first Ariane 5? How do we prevent the Therac 25 from burning more people? In each case, a major inquiry into the causes of the event or events, followed my some (sometimes merely temporary) remedy to ensure that it cannot happen again. This demands knowledge that is specific to the particular technologies involved, and is applied directly to them. Finally, there is a third type of learning which is more general. It could be termed expansive learning. The idea here is that through the first two types of learning, more general knowledge is accumulated. More general principles of, for example, software engineering are discovered, (or often re-discovered), which have applicability far beyond making the Therac 25 a safer machine. Clearly, these three types of learning are not utterly distinct from each other. This is particularly the case of the second and third types. But nonetheless, they differ in their goals, and so spillovers between them are not always simply a matter of course. It can take a concerted effort to shift from one to the other, and in particular to see the more general lessons once the relief at having solved the immediate problem is felt.

Recent economics has emphasized two aspects of learning and innovation.

1. Innovation, and therefore learning, is most often a re-combination of existing ideas or knowledge. There are few completely new ideas, and most "new" things are in fact involve creating combinations of ingredients that have not been combined previously, or even less "originally", re-mixtures, in new arrangements or proportions, of ingredients that have already been combined in one way or another. This is true both of innovation in the sense of developing a new product, innovation in the sense of developing a more efficient process, and innovation in the sense of creating a more efficient organization. It is also true of learning, in the sense of creating new facts, and understanding the links between existing facts.

2. Tacit knowledge can be very important. Much knowledge is codified. That is, it is written down, or recorded in one way or another, to facilitate storage, recall or transmission. The codification of knowledge has changed considerably with the advances in information

and communication technologies, but still, tacit knowledge is always necessary. At its very weakest, the recipient of a piece of codified knowledge must understand the language in which the message is written. Typically this is tacit understanding. But more often than not, the codification is incomplete, in the sense that even if there is no issue of understanding the language, more knowledge is necessary to make use of it.

These two ideas have implications for the economics and organization of learning enterprises.

The importance of tacit knowledge has implications regarding the physical location of research. By its very nature, tacit knowledge is difficult to transmit. When knowledge is codified, it can be transmitted easily---formerly simply be transmitting some physical medium like a book or paper. Currently it is even easier to transmit, as electronic files can be sent extremely quickly to virtually anywhere in the world at zero marginal cost. In today's world, with regard to codified knowledge, distance really is dead. However, the same cannot be true of tacit knowledge (at last not yet, though there are indications that those days may be approaching). It is not written down or recorded, so cannot take advantage of the new transmission technologies. Indeed, we often say that tacit knowledge can only be transmitted through face-to-face contact. In other words, if you wish to take advantage of my tacit knowledge, and perhaps learn it for yourself, we will have to interact directly, not mediated through some communication technology. In order for us to work jointly in an effective way, then, we must be located in the same place. Collaboration at a distance is extremely difficult unless we share large quantities of tacit knowledge. But if part of the point is to pool our different, varied, tacit knowledge, then a single location is necessary.

The idea that effective learning or innovation takes place when researchers are located in one place fits well with empirical observations on knowledge creation. There are many examples of industries in which large amounts of innovation come from a single location. Silicon Valley is the most famous example, but Bangalore is a source of software; Cambridge UK a source of biotech; Milan and other Italian industrial districts a source of innovation in fashion and textiles.

Innovation as recombination leads to different considerations about how learning activities should be organized. Here, the focus is on the raw materials out of which new things are learned. The emphasis lies on exiting knowledge or information as the raw materials on which human ingenuity can operate to create new knowledge. There are two aspects---the amount, and the type of information. To some extent hearing the same information from different sources is valuable---it provides confirmation that the information is correct. On the other hand, though, hearing the same thing over and over eventually loses value. Hearing different things becomes more valuable. Variety in the information inputs is extremely important in effective learning processes.

These comments imply that effective learning and new knowledge creation takes place when the innovators have access to a wide variety of good information. There is a problem then, considering the previous discussion of tacit knowledge. One negative side effect of agglomeration is the emergence of a "dominant design" or "way of thinking". If researchers are too close to each other their way of looking at problems tends to converge. A lack of input from outside can lead to inbreeding and a sort of tunnel-vision. From this perspective, agglomeration can be a bad thing. We want actors to be spread out, so as not to develop too common a view. At the same time, we want them to be connected in such a way that the knowledge that is created or discovered can travel rapidly from one researcher to another.

We seem to have a set of impossible demands: we want researchers to be clustered so they can feed each other, create synergies and critical masses; we want researchers to be independent and not crowded together, so they do not develop tunnel vision; we want researchers to be well-connected so that what the learn is quickly transmitted to colleagues.

The question here is whether it is possible to imagine such a configuration, and if so, what it would look like.

Researchers on a Network

In this paper we address this issue by considering that researchers are located on a network, and communicate with each other over network links. At this point, we restrict attention to certain types of events. Some events, like the Ariane 5 disaster, are single events taking place once and in one location. Here, all available data are located in one place (roughly speaking) and there is a very natural agglomeration of those trying to create knowledge out of the data. Actors tend to be located in one physical or at least organizational location (the ESA in this case). Other disasters are made up of several connected but disparate events. The Therac-25 disaster is an example. Here, the data and the actors investigating it are typically dispersed, both physically and organizationally. Our concern here is with the second kind of disaster. Communication structures typically exist within the organization in the first case. Our interest is whether there is a feasible or efficient way of constructing communication structures for the second case.

Recent research on knowledge networks suggests that indeed there is. The structure to look for is a "small world".

I.2 A Model of Knowledge Creation and Diffusion with Dispersed Agents

It is possible to describe a very simple model which will lend insight into the problems of learning from a disaster when the events are dispersed. The general idea is that there is a population of agents which is geographically dispersed. These agents occasionally receive information about the technology, through some event, and this information both increases that agent's knowledge, and can be diffused to other interested agents. The main question then is how to organize such a system.

The central place of tacit knowledge must be accounted for here. when an agent receives some information, ideally this information will be broadcast quickly to the entire community. Simply codifying it (writing it down in some form) and broadcasting it will not suffice. There are two reasons. First, typically, time is of the essence, as a response to a disaster event must be rapid, in order first to alleviate the problems and second to capture data in real time to the extent possible. Feedback from recipients of the data might take the form of a request for more and different information. In a one-off situation, as disaster events tend to be, this must happen extremely quickly in order to work. The demand for speed implies that the usual publication channels used by scientists are of no value. They are simply too slow. The second reason that codification will not provide the needed diffusion channel is simply that codification is of necessity incomplete. Some tacit knowledge is always necessary in order to understand or use codified knowledge. This is particularly so, when the situation is one of significant uncertainty. Disasters are by definition unusual events, so typically they take place where the science or technology is not well-understood. The technological system has entered a part of its state space which was un-anticipated by its designers. Generally this part of the space has not been explored, and so is necessarily a place where little is understood. What the data are, and how to interpret them is open to question.

When tacit knowledge plays a central role, close personal contact becomes important in transmitting knowledge from one agent to another. This means that in order to understand knowledge flows in this situation, we need to understand how their interaction with the network of agents through which the knowledge is flowing.

We can model this by assuming that our population of agents is located on a sparse network. Each agent is connected directly to a small number of other agents, whom we can refer to as his "neighbourhood". It is over these direct connections that knowledge flows. Thus, to get from one agent, *i*, to another, *j*, information or knowledge must pass through the chain of agents connecting *i* and *j*.

The model is simple: At random times, an event occurs, and one agent receives new information or knowledge. He immediately broadcasts this knowledge to all agents to whom he is directly connected. Knowledge is received and (partially) assimilated by agents in the broadcaster's neighbourhood. Assimilation is not straightforward, though, so when an agent receives a broadcast, he does not immediately absorb everything in it--he is able to absorb only part of it. Economists refer to this ability as absorptive capacity, and agents differ in their absorptive capacities, so some are able to absorb a lot of what they receive, others only a little.

Formally, the knowledge creation and diffusion aspect of the model looks like this.

A population of *N* agents is located on a network. Each agent has a neighbourhood, consisting of, on average *n* agents. The neighbourhood of *i* is defined as the set of agents, *j*, to whom *i* is directly connected. Connections are undirected, so if *j* is in *i*'s neighbourhood, *i* is in *j*'s. Each period an event occurs: one randomly chosen agent, *i*, receives new information, and transforms that information into knowledge. As a consequence, *i*'s knowledge increases according to :

$$v_i(t+1)=v_i(t)*(1+ß_i)$$

where $ß_i$ represents *i*'s ability to create useful knowledge out of new information. Immediately, *i* broadcasts this new knowledge to every agent, *j*, in his neighbourhood. The knowledge levels of those agents increase according to:

$$vj(t+1)=v_j(t)+ a_j*(v_i(t+1)-v_j(t))$$

if the knowledge is new to *j* (*i.e* if $v_i(t+1)>v_j(t)$); and

$$v_j(t+1)=v_j(t)$$

if *j* already has the information ($v_i(t+1)<v_j(t)$).

Our interest is in how knowledge levels grow in such a world.

Communication structure

Clearly, from the description in the paragraph above, the network structure over which communication takes place could be important in aggregate knowledge growth. Consider for example, two extreme structures. First, agents are arranged around a circle, and each agent is connected directly to his *n* nearest neighbours (*n/2* on each side). Call this a "regular structure". Second, again, (for comparability) agents are arranged on a circle, but here agents are simply connected to *n* other agents chosen randomly from the population. Call this a random structure. These two structures illustrate the tension referred to above between agglomeration and dispersion of knowledge actors.

In the regular structure, agents are densely connected locally. Formally, the network is cliquish: my friends are likely to be friends of each other. This local coherence implies that groups of agents exist, and within these groups agents interact heavily. This responds well to the positive properties of agglomeration discussed above. On the other hand though, to move a piece of knowledge from one part of the network to another, it has to travel all the way around the circumference of the circle. This causes slow diffusion.

In the random structure, cliques do not typically exist. My friends are not likely to be friends of each other. This structure responds badly to the discussion of agglomeration above. On the other hand, though, in a random structure, average path lengths are low---it is generally possible to find a short path between any two agents. Diffusion is rapid, and new knowledge spreads quickly among the population.

There are two obvious questions. Is it possible to have the best of both worlds somehow? and Does one or the other of these effects dominate in the model we have described?

The answer to the first is "Yes, the 'small world' has the best of both." The answer to the second is discussed below when we simulate the model.

Small Worlds

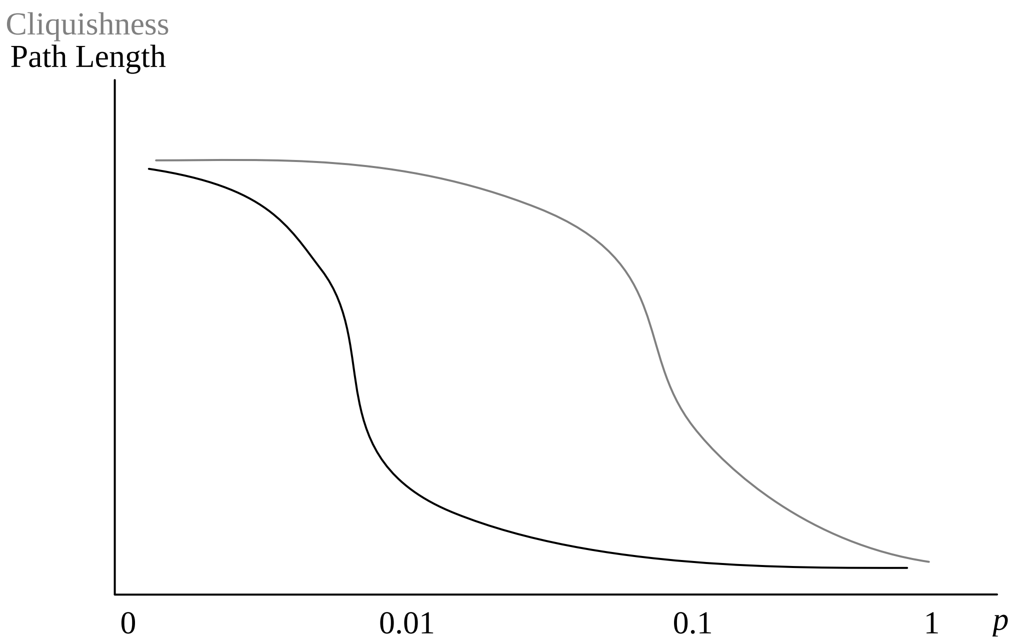

Figure 1: Cliquishness and Path length as a function of the degree of randomness, *p*, in the network

It is possible to interpolate between the regular structure and the random structure using a very simple mechanism, due to Watts and Strogatz, (1998) and Watts (1999). Begin with the regular structure. Consider each link in turn, and with probability *p* break that link and re-wire one end of it to a randomly chosen agent. If $p=0$, no link is re-wired, and the regular structure is maintained. If $p=1$, all links are re-wired, and the random structure is created. For intermediate values of *p*, we have a regular structure with some amount of randomness (increasing with *p*) inserted into it.

The mechanism creates an interesting pattern of cliquishness and path length. Both fall as the amount of randomness increases. This is to be expected. But path length falls very rapidly as the amount of randomness increases, whereas, initially, cliquishness falls very slowly. This implies that it is possible to create a cliquish structure, in which there is considerable agglomeration of activities (in several locations) but in which information can still travel rapidly throughout the population. this is illustrated in Figure 1.

I.3 A Simulation of the Model

To examine the role of network structure we can simulate this model. We artificially create a population of agents, assigning each of them an innovative capacity, beta *i*, and an absorptive capacity, alpha *i*. We create a network among the agents, and then randomly introduce the new information, as described above. The model runs for 10,000 periods, and we record the long run average knowledge level of the population. What we are interested in is the relationship between long run knowledge levels and the structure of the network, described by the parameter *p*, the degree of randomness in the network. Consequently we vary two parameters: *p*; and the range of absorptive capacities.

More explicitly, when we create the population of agents, we assign each agent an absorptive capacity between a^- and $a^- + 0.25$. having set this range, we run the experiment for 1000 different *p* values, plotting long run knowledge levels as a function of *p*. This experiment is performed for 4 different values of a^-: {0, 0.25, 0.5, 0.75}.

What we suggest below is that the structure of the communications system matters with regard to how well knowledge is created. The general idea is that, like anyone else, researchers have a relatively small group of people with whom they regularly interact. Thus when one particular individual diffuses his knowledge, it tends to go to the same people. Perhaps this itself is a problem. One could easily imagine that this repetition creates a redundancy, and better performance could be achieved if, for example, when a researcher diffuses his knowledge, he does so to different people every time. This, on the face of it, could generate a much faster knowledge diffusion in general. We can test this hypothesis by adding a benchmark model to our experiment. Consider another model, identical to the one just described, except that when an agent broadcasts, he chooses n agents at random from the population (rather than to his *n* direct neighbours).

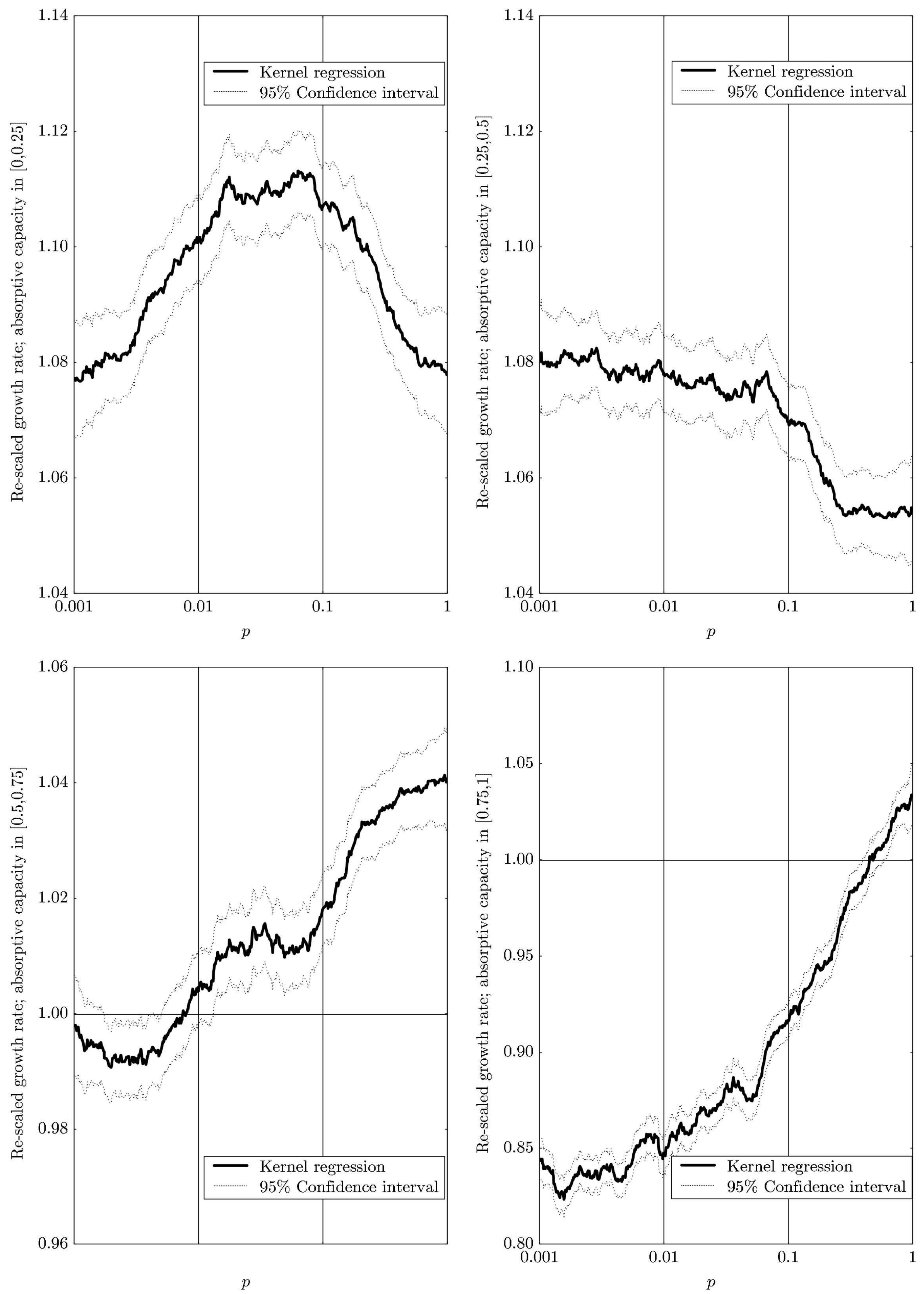

Figure 2: Normalized long run knowledge levels versus randomness in the network, *p*, for 4 ranges of absoprtive capacity

Simulating this model of knowledge creation and diffusion produces several conclusions about the relationship between communication structures and knowledge growth. First,

having structured, rather than random, communication is in fact a good thing---knowledge growth is faster when communications are structured compared to random communications. Second, which structure it is matters. When it is difficult to absorb what others have learned, the small world dominates. As it becomes easier to absorb, the small world effect loses its dominance, and in fact if absorption is very easy, a random world is the best.
These results are captured in Figure 2.[1] There are four panels, each panel representing knowledge growth under a different absorptive capacity, running from low absorptive capacity in the top left, to high absorptive capacity in the bottom right. In each case, the outcome is compared to the benchmark model of random communication. This is done by normalizing so that the random communication case with the same absorptive capacity levels (defined by a^{-}) has a long run knowledge level of one. The dominance of the small world region is obvious for small alpha values. As it becomes easier to absorb others' knowledge, this effect dissipates and the random world, with short path lengths becomes increasingly attractive. similarly the value gained from having structured communication falls as absorption becomes easier. Indeed, by the time absorption is relatively straightforward (panel in the bottom right) having structure to communication is largely deleterious.

I.4 What is driving these results?

In a diffusion model the value of short paths is clear: whatever knowledge is created is spread rapidly among the population. Growth from diffusion is rapid, and further, innovation takes place from a higher starting point. Thus growth from knowledge creation and distribution is more rapid. This creates a tendency for a random network to be most effective in creating knowledge growth. We see in our results that under some conditions (when absorptive capacity is high) this is the case. But it is not always so. when absorptive capacity is relatively low, cliquish graphs perform better. Thus there must also be some value to cliquishness which dominates under some conditions. In a cliquish world there is considerable redundancy among the connections---any agent who broadcasts to *i* has almost certainly received the same broadcasts that *i* has. Suppose *k* innovates and broadcasts to his neighbours, including *i*. They all partially absorb. But when *i* receives a second broadcast, from someone else in his clique, he is to some extent being re-exposed to the information contained in the first broadcast. Agent *i* absorbs some more information from the first broadcast. In this way, through the indirect re-exposure to earlier broadcasts, *i* can learn everything embedded in *k*'s innovation. Under what conditions is this an important effect? When absorption is difficult. When a^{-} is small, though, repetition is the only way to learn. Cliquishness can compensate for low absorptive capacity. If a^{-} is close to 1 though, repeated broadcasts of the same information serve no purpose. Agent *i* has already learned it, so the dominant effect of the redundancy in cliquish graphs is to slow diffusion to distant parts of the network.
Why then is the most highly cliquish graph not the most efficient when a^{-} is small? It arises from a tension between local and global diffusion. Cliquishness is effective in local diffusion and learning. Because it implicitly involves long paths, though, it is detrimental to global diffusion. Thus in a highly cliquish world, cliques grow at different rates, some rapidly, some slowly. But in a very regular world, it is difficult to pass information among cliques, so rapidly growing cliques benefit only themselves. In a small world, however, the presence of some shortcuts permits `leakage' between the cliques, and rapidly growing cliques can assist their more slowly growing neighbours as knowledge leaks from the former to the latter.

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1 In each panel of figure 2 there are three curves. The dark curve is the relationship estimated using a Kernel regression. The two lighter curves show the 95 percent confidence intervals around the Kernel regression estimate.

I.5 Conclusion

When a learning opportunity involves unexpected events, occurring to dispersed agents, communication of whatever is known among the interested agents is vital to accumulating knowledge quickly. What we argue in this paper is that the (social) structure over which this communication takes place can be vital. For some types of disasters this is not a troublesome issue. When there is a single event, and the people involved in investigating it are located together, information automatically passes quickly among them. However, when the disaster involves several events, located at distant points in space, such as the Therac-25 example, then information flows become a very important issue. In these cases, rapidly putting together the information that is available is vital in ensuring a quick and efficient learning process.

In the case of technological disasters, we can expect that there is a problem of interpretation of the data that are presented. Further, because time is usually of the essence, traditional techniques of codifying, checking, reviewing the information diffused will be much too slow. Both of these suggest that communication will be in some ways partial, and that the ability of any agent to absorb what is sent by another agent will be muted. Our model of this process suggests that in these circumstances one network communication structure dominates: that of the small world. This conclusion is consistent with recent empirical studies of innovation both in industry and academe. Communication networks of innovators tend to form into small worlds. They do this over time, but the successful ones retain this structure for long periods.

It is important to contrast the type of communication being discussed here with two other types of communication that do exist in several industries. Mandatory accident reporting exists in some industries, the most obvious being medicine. Here the knowledge flows are very specific---from an agent to a central hub, (for example the Food and Drug Administration in the US) and from that hub to most agents in the industry. This is very valuable in alerting agents to the possibility that strange things are happening, and can serve as the impetus for a long distance link between two distant cliques of agents who are observing similar phenomena. But this is not enough. Those potential links must be activated in order to create the small world, and they must be used to pass current research results about the incidents, rather than simply reports that they have occurred. This reporting can be important in beginning the process of activating a small world communication structure over which research can be carried out, but it can do little more than this.
The second type of information flow is what we might call the safety meetings for a general assembly. Often, at annual meetings of industry associations there are sessions on safety. Here, the network structure is again a star: knowledge flows from one agent to many agents. Equally important, though, is that the knowledge flow is very largely one way. There is little feedback. While this flow can pass important information to many people about the latest safety developments in an industry, it is not a structure that is conducive to rapid joint learning. Flows must be two-way, and there must be critical masses of people working together to create the situation the renders learning fast and pertinent.

Regarding policy with respect to technological disasters, the implications are clear, at least at a very general level. The communication structure among those agents attempting to learn from the disaster, whether learning about response, repair or more general facts, should have the architecture of a small world. But who are these agents? The answer to this question is clearly that it differs from industry to industry: for some industries there are active safety organizations; for other industries there is simply an industry organization, in some cases having a sub-section of the industry responsible for research. In other industries there are no existing organizations. But the policy implication is clear. In any industry in which a technological disaster is possible, the industry organization must create a structure within which communication takes place rapidly after a disaster. For virtually all of these industries some sort of industry organization already exists. The task, then, is to ensure that some part of those organizations take the responsibility to create communication channels which can be activated following a disaster. This involves establishing cliques, and formalizing the means by which there is inter-clique communication. Cliques must have the property that the members of them can and will communicate rapidly and easily among themselves. This suggests the importance of geographical location, and disciplinary affinity. A policy maker can simply mandate this, and perhaps provide assistance in creating the structure. Each member of the organization must belong to a clique within the structure, and this clique must have the property that its members are familiar with each other, and interact frequently and easily. To sustain this is the issue, and this certainly takes resources. The only way a clique can maintain this dense communication is by meeting together, whether or not there is a disaster. Thus one criterion for creating a clique is that its members have enough in common that they can benefit from meeting even in the absence of a disaster. Any industry organization is likely to have several of these cliques. The second aspect of the small world is the inter-clique linkage. This is more difficult to implement through policy. However, policy can be formed so that intra-clique meetings are subsidized through policy but only on the condition that the over-arching industry body gives evidence that inter-clique links exist and are strong. If this is implemented, then the small world network is in place, and ready to be used if a disaster occurs.

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Chapter 2

Diffusion of learning from a disaster : a statistical analysis

II.1 Introduction : the diffusion of knowledge

There are three fundamental spaces across which any knowledge and information can diffuse: temporal, geographic, and industrial. Just because knowledge can diffuse across these spaces, however, doesn't necessarily mean it does, and, even if it does so, it may not happen instantaneously. The underlying basis for the fact that knowledge does not diffuse instantaneously across each of these three spaces is due to the presence of costs or frictions which slow the rate at which the knowledge can travel. In some sense there is an existing network of agents, organisations, or a combination of both, across which knowledge can potentially diffuse.[2] On the other hand, there exist costs of transmitting the knowledge between the agents or organisations due to naturally occurring frictions which slow down this diffusion. For instance, thinking in terms of geographic space agents and organisations are separated by physical distance and it takes time and resources to transmit knowledge across this distance, typically costs rising with increases in distance. Furthermore, different modes of communication, such as email, telephone, postal services, shipping services, face-to-face (say via travel), facsimile, take different amounts of time, incur different monetary costs, and experience different reliabilities and qualities of information transfer. These same factors also affect the diffusion of knowledge over time and between industries. Furthermore, the benefits to agents and organisations in the network of actively transmitting knowledge depend on other factors such as whether or not they earn monopoly rents from keeping the knowledge private, whether they can obtain knowledge useful to them in the future from passing on the knowledge they have, or in the case of Atomic Energy of Canada and the Therac-25 failure any potential legal liability from knowledge being made public, and so on.

Knowledge gained from the Therac-25 failure can potentially diffuse across each of the three spaces mentioned. On the other hand, in practice not all of the knowledge may diffuse at once but may take time to filter through to various relevant parties, since the failures occurred in localised geographic spaces and radiation therapy machine producers and users exist over multiple countries and continents, and since there are at least three industries involved in the failure (the radiation therapy machine industry, the computer industry, and the radiation therapy industry). In this section I will briefly explore what we currently know about each of these three facets of the diffusion of knowledge and from this derive hypotheses about what we would expect to occur regarding the diffusion of knowledge emanating from the Therac-25 failure.[3]

II.1.1 Diffusion across time

One of the first studies of the diffusion of knowledge over time was Griliches (1957), who found that the diffusion of hybrid corn in the United States followed a logistic or S-shaped curve. That the diffusion of knowledge is not instantaneous is a result of two factors: that knowledge has to be transferred across networks of people or organisations and that the knowledge being transferred tends to be of unknown merit. Consider first the influence of information communication networks. The impact of different institutional structures on the diffusion of information is studied by who Mitchell (1999) who studies what happens when agents choose how many other agents with whom they wish to connect. He finds that the existence of

[2] Regarding the theory of networks and the diffusion of innovations see for example Cowan and Jonrad (forthcoming), Deroian (2002), and Mitchell (1999).
[3] This will not be an exhaustive review of the literature since doing so is not the primary aim of this work and would be an enormous undertaking in of itself. In addition there already exist such reviews, for example Reinganum (1989) or Stoneman (2002) .

information hubs such as professional associations can speed up the rate of diffusion because they allow the costs of information communication to be shared while still allowing individuals to capture the full private benefits of the information.[4] On the other hand he finds that the presence of network effects can slow down the rate of information diffusion because people try to free-ride on the connection efforts of others. Deroian (2002) highlights the social dimension of knowledge diffusion by studying the impact of collective opinions on the merits of knowledge or an innovation, including opinion leaders (experts) who have a disproportionate impact on the collective opinion, on the decision of agents about whether or not to accept or reject an innovation. He finds that if people are receptive to others opinions and learn from each other then a common acceptance or rejection of a technology can occur (the results being sensitivity to initial conditions). There is a network externality at work here and if big enough everyone does the same thing. If agents are not sufficiently receptive to the opinions of others then no common opinion results. In this case the initial heterogeneity dominates as the network externality is too weak. For given social receptiveness and learning speed, increases in network size lead to faster diffusion rates as it is the sum of opinions that matter. Finally, considering local versus distant knowledge, Cowan and Jonard (forthcoming) show that networks which are predominately local or global in flavour are fastest at diffusing knowledge compared to networks which have a mix of local and global connections. On the other hand, they also show that networks structure which are predominately local but have a few global connections cause the widest diffusion of knowledge. Small world networks, as they call them, are not only good at diffusing knowledge from local sources because of their dense local networks but are also good at acquiring knowledge from distant networks because of their global connections. Even though the small worlds only have a few global connections they are sufficient to ensure access to distant expert knowledge.

Apart from the network across which the information or knowledge is being communicated we would also expect facets of the knowledge itself to affect its diffusion. In particular, given that the recipient of the knowledge does not have the knowledge in the first place he would be unlikely to know its complete usefulness (if so, he would then essentially know the knowledge and wouldn't need to acquire it). This uncertainty about the usefulness of the knowledge being communicated (in this case in terms of whether or not an innovation should be adopted) would be expected to slow down its diffusion as the decision to acquire the information is similar in nature to the decision about whether or not to exercise an option. This feature of the diffusion process is studied by Kapur (1995) who considers firms who have to decide whether or not to adopt an innovation with uncertain cost, where the adoption sends a noisy signal about the cost to other firms thus creating an informational externality. The firms have to balance up the opportunity cost of expected profits from adopting the technology versus the expected gain from waiting and learning from the adoption of others. He finds that the noisiness of the signal and the speed with which beliefs are updated determine the speed at which the technology diffuses. If the signal is very noisy and the speeds are updated slowly (say because of a dominant preconceived heuristic framework) then none of the firms adopt the technology. On the other hand if the signal is sufficiently informative and firms update their beliefs sufficiently rapidly then the familiar S-shaped adoption curve eventuates.

This logistic or S-shaped curve diffusion pattern has appeared repeatedly in empirical studies of the adoption of innovations over time and the findings of these duties are summarised by

[4] Although as Mitchell also finds, the structure that allows the widest or fastest diffusion of information may not be socially optimal since the effects of the informational externality may cause too much information to be transmitted relative to the costs of doing so.

Stoneman (2001, Chapter 2).[5] It is worth noting that while the S-shaped empirical pattern seems to be a stylised fact regarding the adoption of technologies, that the exact shape of it (reflecting differences diffusion rates) can differ substantially across industries, regions, countries, and technologies. In theory we would expect such differences in diffusion rates to occur because of factors specific to the industry, region, country, or technology, being examined. We can see why this would occur, as well as learning more about the types of specific factors that affect the diffusion of knowledge by quickly considering a couple of recent empirical studies.

Consider first Fuentelsaz, Gomez, and Polo (2003) who study the intra firm adoption of ATMs by Spanish banks. Among other factors affecting the diffusion of ATMs, the find that reduced uncertainty about the innovation increases the diffusion rate whereas greater industry concentration reduces the diffusion rate. The former implying that if the merits of an innovation are unknown then it pays to wait and gain more information before adopting (for knowledge, if there is a cost to getting and absorbing the information then it pays to wait to see how valuable the information is before trying to obtain it). The latter results from there being less competition and so less pressure to innovate and improve product quality or variety. They also find that the larger a firm is, the slower the diffusion rate (because smaller firms require proportionately less investment to adopt and also because there is more decision making inertia in larger firms), and the greater the financial resources available to a firm, the faster the diffusion rate (because they can afford to finance the investment at less cost).

Another study is that of Menanteau and Lefebrve (2000) who investigate the diffusion of lighting technologies (incandescent lights, fluorescent tubes, and fluorescent bulbs) identifying several factors affecting their diffusion. Expectations about the future economic environment and uncertainty about the worth of the specific technologies were both found to affect the diffusion rate – a slower rate of diffusion the more pessimistic were expectations about the future environment for a technology and the higher the uncertainty surrounding its worth. The presence of bounded rationality heightened the effect of the uncertainty and could also lead to bandwagon or herd type of behaviour. There also seemed to exist a natural inertia to adopting a new technology due to a heuristic model which favoured the existing technology (or knowledge) and to switching costs arising from technological complementarities. Finally, there seemed to exist economies of scale through the presence of significant fixed costs and learning by doing, leading to increasing returns in the adoption of the lighting technologies. As a result, network effects were present and random shocks could lead to a path dependent outcome.

II.1.2 Diffusion across geographic space

The diffusion of knowledge over geographic space has usually been studied in two settings: the first relates to spatial externalities in attempts to explain urban agglomerations in the form of cities and the patterns such agglomerations take such as concentrations of specific industries in one geographic region or place; and the second in the form of spillovers across countries in attempting to judge whether or not countries growth rates converge or diverge in attempts to explain persistent income and economic growth differences across countries.[6] As Bottazzi and

[5] Although as Stoneman (2002, p. 13) points out some researchers have suggested that the Gompertz curve may better represent the diffusion process.

[6] See Breschi and Lissoni (2001), and Branstetter (2000) for surveys of the literatures on spillovers relating to regions and across national boundaries, respectively.

Peri (2003) point out, it is likely that a new idea has two parts: the codified part such as patent which is a full public good with wide spillovers; and the non-codified or tacit part which is embodied in people, diffuses mainly through personal contacts and face-to-face interactions and is more of a local public good and fades as space increases.[7] The extent of knowledge spillovers across space and their size are likely to depend on the importance of each of these two types of knowledge.

The typical focus of issue regarding international spillovers is whether or not technological knowledge spillovers are local or global. The sources of these spillovers are posited to reflect linkages between countries emanating from trade and foreign direct investment, although the presence of other linkages through international labour markets, migration flows, international scientific communities, cross-border telecommunications (for example email newsgroups, radio and satellite television broadcasts, and the internet), and even tourism, could also be expected to used to diffuse knowledge across countries. There exist many factors that affect the rate at which knowledge and information diffuses. When thinking about diffusion across national boundaries such factors include the presence or absence of multinational enterprises (MNEs), the cost, capacity, and quality of telecommunication services, the cost, availability, and speed of transportation services, the existence or absence of a common language, the degree to which cultures are open to knowledge and information and to interactions with people from other countries.

One example of this type of study is Keller (2002) who finds that technological diffusion is localised with the amount of spillovers from R&D expenditures halving at a distance of 1,200 kilometres. Interestingly, he also finds that the degree of the localisation of these spillovers has decreased over the period 1970-82 to 1983-95 suggesting that other factors such as telecommunications and travel costs are important in affecting the size of these spillovers. Another is Xu (2000) who finds that MNEs act to diffuse knowledge across national boundaries. His results also highlight the interplay of the different factors affecting diffusion rates since he finds a minimum average level of human capital that needs to be present in a country before such diffusion can occur and so on this dimension developed countries benefit considerably more from the presence of MNEs than do less developed countries. This importance of human capital in implementing innovations and new knowledge reinforces earlier work by Bartel and Lichtenberg (1987) who find that the relative demand for educated workers declines as the age of plant and equipment declines and interpret this as evidence consistent with highly educated workers having a comparative advantage in implementing new technology vis-à-vis less educated workers.

In a similar vein to Xu, van Pottelsberghe de la Potterie and Lichtenberg (2001) study the extent to which foreign direct investment (FDI) transfers technology across borders. They find that inward FDI does not induce substantial technology transfers from the home country to the host country (that is, there are no significant international R&D spillovers from FDI) and argue that it is because the home country want to exploit their advantage and not give away this advantage to host country firms. On the other hand, they also find that MNEs invest in host country firms to acquire technology which benefits productivity in the home country. Furthermore, they find that economies benefited more from foreign R&D through international trade in 1970s than the 1980s, while this was the reverse from outward FDI, imports transferred R&D from other countries (presumably because the imports include goods that embody foreign technology), and large countries receive proportionately more R&D benefits from outward FDI (that is, acquiring firms in other countries) than from imports, compared to small countries where it is the reverse.

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[7] Cowan and Foray (1997) discuss the differences between codified and tacit knowledge and the implications for the diffusion of knowledge.

These findings on the impact of trade and foreign investment on technology diffusion is reinforced by the work of Hu and Jaffe (2003). The authors analyse knowledge diffusion from the US and Japan to Taiwan and Korea from 1977 to 1999 using citation data for these countries as an indicator of knowledge flow. The main finding of Hu and Jaffe is that Korea cited Japanese patents much more heavily than US patents whereas Taiwan cited Japanese and US patents roughly equally. This coincides with the extent of linkages between the countries through trade and FDI. Korea had a restrictive FDI environment and openly promoted technology transfer through procurement of turnkey plans and capital imports which led to Japan dominating Korean capital imports and FDI into Korea. On the other hand, Taiwan had a more liberal environment and the US and Japan were roughly equal in terms of FDI into Korea. The authors thus argue that these factors significantly affect the diffusion of knowledge and differences in them cause different diffusion paths in countries.

These same types of factors are also relevant across regions within a country, but normally there are more factors present that positively affect the diffusion of knowledge because everyone speaks the same language, people across different regions have the same underlying culture, and since spatial differences tend to be smaller within a country than between countries the costs of travel and communications are lower. That spatial spillovers occur is shown in a study of urban based knowledge spillovers by Henderson, Kuncoro, and Turner (1995) who find evidence consistent with the presence of dynamic externalities in metropolitan areas in the United States. For both mature and new high technology industries this takes the form of a build-up of knowledge associated with interactions between firms in the same industry. For new high technology industries this also takes the form of a build-up of knowledge or ideas associated with historical diversity.

Whether or not spatially based knowledge spillovers exist over greater distances than just urban areas is the focus of Bottazzi and Peri (2003) who aim to identify and estimate the effect of research externalities in generating innovation across 86 European regions from 1977-1995.[8] Dummies are included to capture region-specific factors. They find that spillovers are very localised and exist only within a distance of 300km. The estimated spillovers are very small with a doubling of R&D spending in a region increasing innovation in the region by 80-90% but only 2-3% in regions within 300km of it. The amount of human capital (share of college graduates in the population of a region) is associated with large positive increases in innovative output, and there is no evidence of human capital spillovers. There is evidence consistent with at least some of the spillovers being intra-industry, as closeness in technological proximity as opposed to spatial proximity also matters. A border effect seems to be present with spillovers higher for regions within 300km that are in the same country versus those in different countries. Interestingly they argue that if codified knowledge diffuses widely but does not directly affect productivity very much whereas tacit knowledge directly and significantly affects productivity but relies on informal and close contacts and is more localised, then they the may be picking up the tacit knowledge spillovers from people who diffuse knowledge by having have frequent interactions.

Reinforcing the previously discussed results and also hinting at channels through which spillovers and thus diffusion of knowledge occur is work by Anselin and Varga (1997) who attempt to assess whether or not university R&D and private R&D interact with each other, and

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[8] The regions do not cross national boundaries and are territorial units classified by Eurostat with the distance between them classified as zero if the regions share borders and the shortest air distance between their boundaries if they do not share borders.

if so to what degree, as well as the spatial extent of spillovers from private and university R&D. Analysing data on private R&D and university research, first at the state level for 43 US states and then at the metropolitan level for 125 US metropolitan statistical areas they find Both university research and private R&D are significant and important in determining innovative output at the state level. Both university research and private R&D are significant and important in determining innovative output at the MSA level. University research has an indirect local effect on innovation by inducing private R&D activity (but not vice versa) within an MSA but these spillovers of university research do not extend beyond this. Spillovers from university research extended over a range of 50 miles from the innovating MSA

II.1.3 Inter-industry diffusion

The primary issue of the diffusion of knowledge across different industries seems to be whether or not it actually occurs, compared to the diffusion of knowledge across time and geographical space, seems to have elicited relatively little study to date.[9] One of the first people to discuss the diffusion of technologies and knowledge across industries was Schmookler (1966) who hypothesised that an industry could experience an improvement in its productivity not from R&D within the industry but through R&D in other industries embodied in intermediate goods purchased by the industry.

The role of inter industry technology flows in promoting productivity growth is studied by Griliches and Lichtenberg (1998) who use data for the United States from 1964-78. They classify R&D that can occur in an industry into three types: own process R&D; own product R&D; and product R&D embodied in inputs purchased from other industries. They investigate whether or not each has an impact on own industry productivity and, if so, how much of an impact. They find that product orientated R&D performed within an industry has less effect on the industry's TFP growth rate than process R&D or R&D embodied in purchased inputs. The evidence supports own product R&D having a significant and positive impact on TFP growth of the industry, in contrast to earlier studies which found that it was insignificant. Process R&D and R&D embodied in purchased inputs seems to have a smaller impact on TFP growth from 1974-78 than 1969-73. Own process R&D has the primary impact on TFP growth rates compared to R&D embodied in purchased inputs (that is, inter industry spillovers do exist although they are not nearly as important as was what goes on within the industry).

Another study, which has the potential to captures aspects of inter industry spillovers, is that of Los and Verspagen (2000) who aim to determine the importance of knowledge spillovers at the firm level (since this is seen as the source of growth in endogenous growth models) using data on US manufacturing firms for the period 1974-1993. The authors distinguish between two types of spillovers: rent spillovers are caused solely by product innovations and which they claim are not true spillovers because they tend to be caused by measurement errors; and knowledge spillovers where firms and people gain knowledge directly from the producer of it without paying for it (it has a public good characteristic and the claim is what is truly meant by a spillover).[10] They find that there is evidence of both rent and knowledge spillovers between firms, although knowledge spillovers seem to be the stronger of the two. Given in both that the spillovers can occur between

[9] At least according to the metric of items available through the Econlit database.

[10] To distinguish between the impact of the different types of spillovers the authors construct four measures of R&D available for spillovers to each firm: the first two use European Patent Office data to calculate weighted R&D stocks; the third tries to capture inter-industry rent spillovers using input purchasing information; and the fourth is a crude measure of indirect knowledge available by taking an unweighted sum of the information stocks of all other firms.

firms in different industries (although the rent seeking spillovers are more likely to involve firms in dissimilar industries) then the results again suggest that inter-industry spillovers are present.

II.2. Newsgroup and Citation Data Analysis

The tables in Appendices A (section II.3) and B (section II.4) contain data on two types of information flows relating to the Therac-25 failure. The first appendix contains postings to four collections of newsgroups from 1985 until 2003: two individual computer related technology newsgroups; one group of engineering newsgroups (thirty-one in total); and the last group of medical newsgroups (thirty-one in total). Appendix B contains data on citations of a book which was published in 1995 and which is seen as an authoritative record and analysis of the Therac-25 failure. What I will now do is analyse the data in light of the theoretical and empirical work on knowledge spillovers mentioned in the preceding section.

Before analysing the data it is worth keeping in mind a few important events and when they occurred, so as to get help put the information flows in the newsgroups and citations into an accurate context. For a start, there were seven Therac-25 failures with three occurring in 1985, two occurring in 1986, and the last overdose in 1987. The first newspaper report of the problems with the Therac-25 as far as we are able to ascertain occurred in 1986, the first mention of problems with this machine in a trade journal occurred in 1987, and the first academically analytical articles occurred in 1990 with a major article in 1992.

II.2.1 Newsgroups

The first thing to note is that the software engineering newsgroup (SEN) had far more postings than the other three with 153 compared to the combined 102 of the others. Over the nineteen years of data this implies an average number of postings per year of 8.05 for SEN, 2.47 for the comp.risk newsgroup (CRN), 1.84 for the collection of engineering newsgroups (ENN), and 1.06 for the collection of medical newsgroups (MEN).

The identity of the senders of the postings varied by newsgroup. For the SEN postings 61% originated from commercially based senders and 28% were from academia. This is somewhat similar to ENN where 77% of the postings were from commercial senders, although 17% were affiliated with a government. For MEN and CRN the majority of senders were from academia, although for MEN commercially based senders constituted the rest of the senders and a significant minority, whereas for CRN government and commercially affiliated senders were roughly equal and each made up a fifth of them. The types of postings sent, and therefore type of information communicated, differed quite markedly between newsgroups. Two types of messages were considered, personal messages which can probably best be thought of as communication of tacit knowledge and announcements which can be thought of as indicators of communication of codified knowledge. If this is a realistic way of thinking about the information being communicated then most postings in CRN, SEN, and MEN were of a tacit nature, whereas for ENN the share of tacit and codified knowledge communicated was split approximately evenly.

Trying to make sense of the data is tricky at best, but it probably goes something like this. First, the CRN newsgroup is under the direction of a professional group, the Association for

Computing Machinery, and specifically deals with computers and public policy. Information of this topic seems less directly relevant to businesses than others, which seems to be the case and is consistent with the affiliations of the senders and the type of postings. SEN and ENN have the potential to be very relevant to businesses, since they deal with engineering related knowledge, and the data is consistent with this possibility as postings to them are dominated by commercially affiliated senders. MEN would seem to have idiosyncratic factors that affect who sends messages to it and more information is needed to say anything about this pattern.

There is no clear pattern with respect to the posting of newsgroup messages over time with SEN having a roughly S-shaped look to it, CRN having an exponentially declining distribution, and both ENN and MEN having the most of their postings in the middle interval of the time period considered. See figure 1.

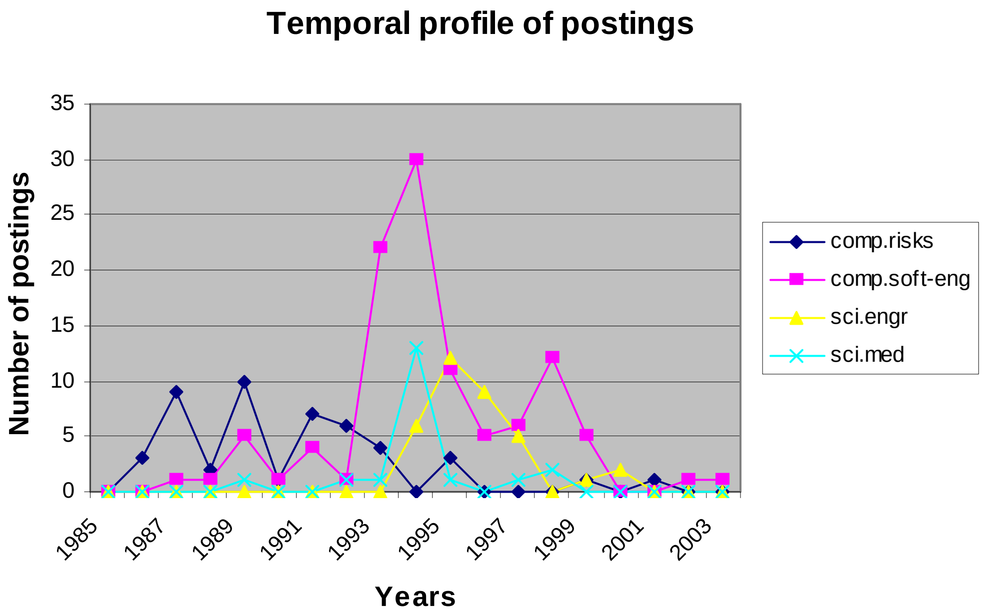

Figure 1

That SEN is S-shaped in nature and seems to be dominated by commercially based senders is suggestive that knowledge diffuses through it operates in a similar vein to that posited by Deroian (2002), with early posters, knowledgeable experts, and as long as people are sufficiently receptive, widely diffused knowledge about the innovation. In this case, it too the better part of 10 or so years before this happened from when the ``innovation'' occurred (here the failure). The distribution for CRN is not that surprising given that it is in effect an alarm system, with the failures causing some ringing of bells and thus an initial flurry of postings and the a quick fading off as the no new failures occurred. The patterns for ENN and MEN may reflect the fact that the failure was originally traced to software, which is the natural home of SEN, and once sufficient knowledge and diffusion of information had occurred in this area, it spilled over to engineering more widely and also the medical industry. This would be an inter-industry type spillover and suggests that it can take many years from the initial breakthrough in the source industry for the spillovers to occur and suggests a strong lag feature may be needed in empirical models used for estimation of these spillovers.

There is a clear pattern regarding the geographic area from which the senders of the postings are located with a strong majority of the postings in all newsgroups (ranging from 85% to 90.3%)

originating in North America. See figure 2. Notably, this is precisely where the failures occurred and where the first and many subsequent information sources were located. This may be interpreted in terms of the localisation of knowledge spillovers found by authors such as Keller (2002), especially since most of the other postings came from first other English speaking countries (ranging from 2.8% to 10%), and the other European countries (ranging from 1.9% to 5%). The rest of the world did not feature at all, even in a minor way.

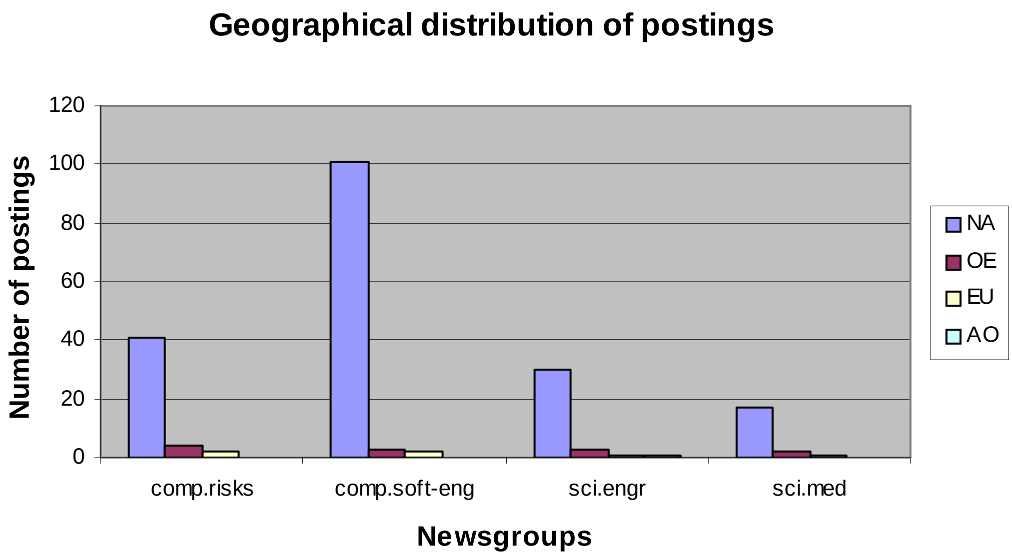

Figure 2

If we think of postings as crude indicators of knowledge spillovers we would expect that English speaking countries would enjoy more spillovers of knowledge about Therac-25. First, they share the same language, which Keller (2002) highlighted as a factor positively affecting spillovers. They also share a similar cultural and institutional heritage, such as common law legal systems, and the results of Bottazzi and Peri (2003) show that spillovers are more likely to occur within a border, probably reflecting factors such as a common culture and set of institutional structures, than across borders. Given that the average level of human capital in countries outside English speaking and European ones is low, and Bartel and Lichtenberg (1987) tell us that this environment would make these countries less receptive to learning and knowledge diffusion about technological innovations. Added to this is also a basic infrastructure that can be used to communicate information as in some parts of the world, say Africa and the Middle East, the costs of communicating information are very large or facilities to communicate it, at least widely, simply are not present. Furthermore, those countries in this group in which the average level of human capital is large, such as Japan, and some East Asian countries, have very different languages and cultural institutions, suggesting that they would be less receptive to information spillovers emanating from outside their boundaries.

II.2.2 Citation Data

The knowledge diffusing through citations has quite different features compared to that diffusing through the newsgroups, assuming that citations of the Leveson (1995) are a reasonable approximation of the diffusion of knowledge about the Therac-25 failures. First, as shown in figure 3, the diffusion of knowledge about Therac-25 is geographically far less localised when using citations than when using newsgroup postings. For example, if counting citations by number of author's counts of citations are approximately evenly split between those located in North America, other English speaking countries, and other European countries. There is even diffusion to other countries, in the case of counting citations by authors 12.8% of the citation count was to other countries. Interestingly though, these other countries are predominately Japan or Korea, which have high levels of human capital and capital infrastructure, again supporting the results of Bartel and Lichtenberg (1987) that a sufficiently high level of human (and in this case physical) capital needs to be in place for diffusion to occur.

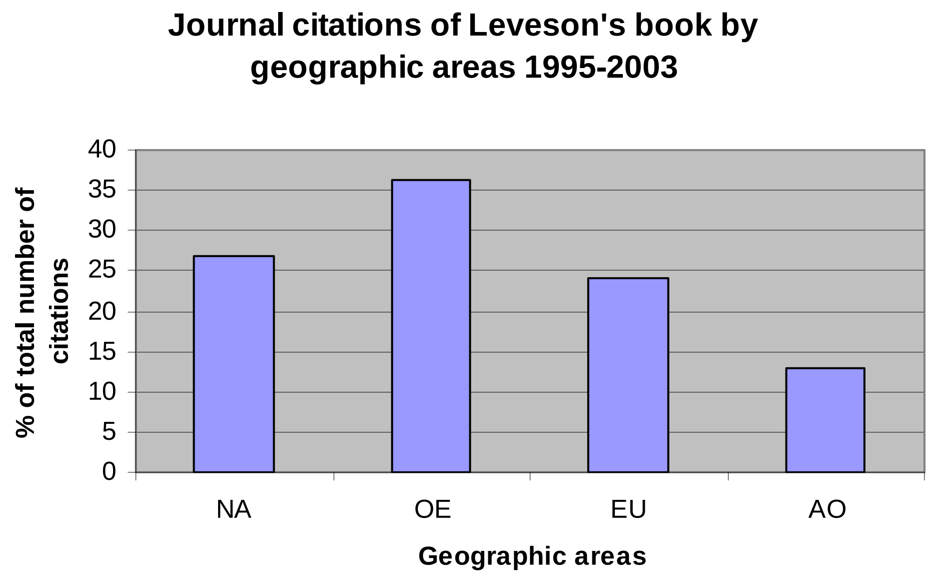

Figure3

Why the difference compared to the newsgroups? The answer is obvious in that citations are of a codified piece of knowledge, which is essentially a public good and much more easily transferred across national borders, and cultural and language divides, than tacit knowledge, which newsgroup postings represent. This result supports the results of Bottazzi and Peri (2003), who find knowledge spillovers to be highly localised within Europe and posit they are picking up the difficulty of transferring tacit knowledge. It also supports the results of Keller (2002) though since it suggests that codified knowledge can diffuse widely.

Regarding affiliations of the authors, most citations, no matter how the citation counts are calculated, are academic, with more than 75% of the citations being from academically affiliated authors. Then at roughly 15%-20% are authors affiliated with commercial organisations. Government affiliated authors make up less than 5% of the authors on the whole. See figure 4.
The difference between tacit knowledge communicated through newsgroups and codified knowledge communicated through articles is also revealing and again highlights the difference between the practices of businesses and academics. Since codified knowledge is a public good, commercial organisations have a much lower incentive to communicate knowledge in this form than do academics who in fact gain reputation and promotion from doing so.

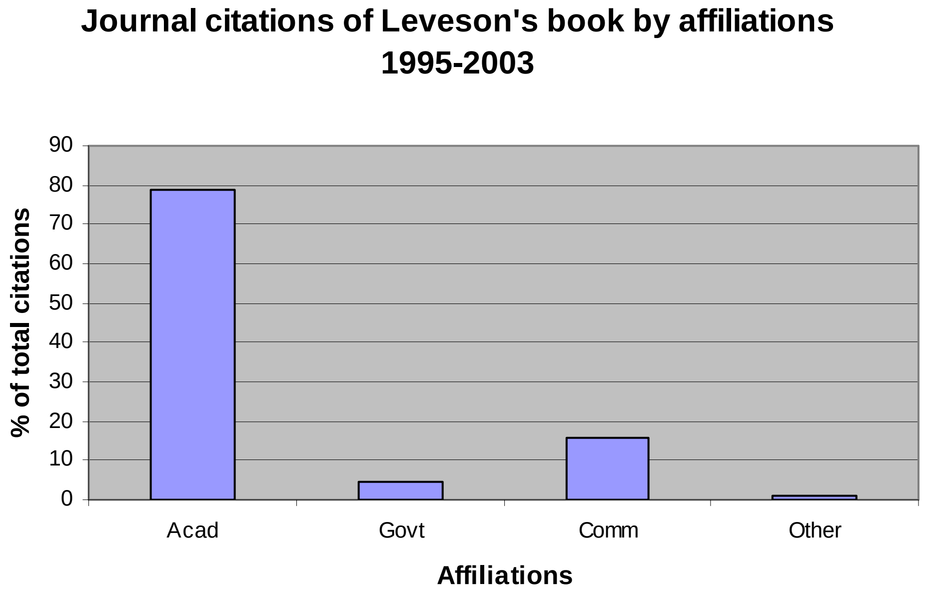

Figure 4

Finally, roughly 60% of the citations were on the subject of computing, roughly a third were on the area of engineering not relating to computing, and the remained (in the range of 4%-8%) were split between medical and other (typically on the subject of ethics). See figure 5. This is different from the newsgroup postings where about 80% were in one of the two computing newsgroups. It seems that again codified knowledge lends itself to large inter industry spillovers than does tacit knowledge.

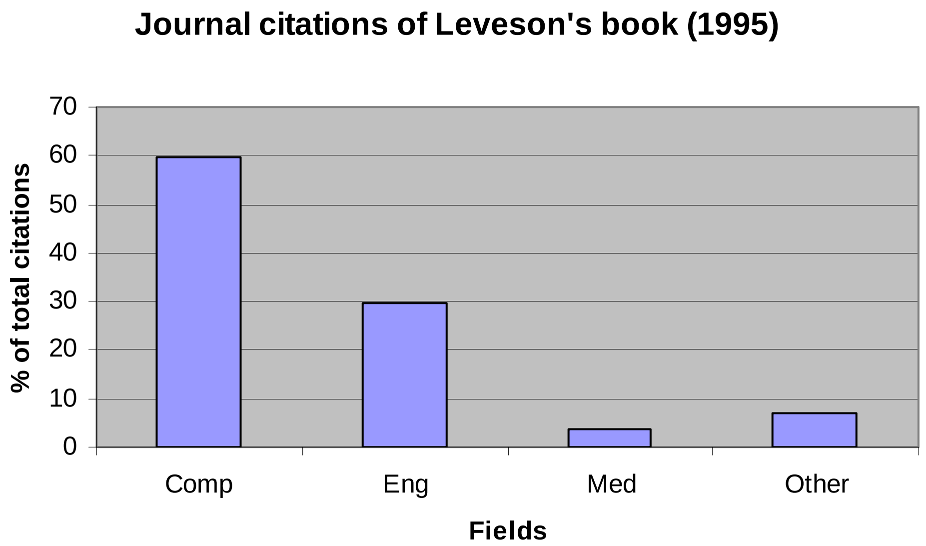

Figure 5

II.2.3 Final Comments

The data examined have some interesting implications. Just looking at the newsgroup postings, and considering North America, the data seems to be consistent with the work on networks (see chapter I) about the network structure that optimises diffusion of knowledge. The data presented is consistent with North America having a strong local communication network but also having a few long distance connections. In chapter I's framework this situation maximises the diffusion of knowledge and thus would help to explain why North America, and particularly the United States is seemingly so innovative. It may simply reflect that it has a knowledge communication network that is very efficient at diffusing information both locally and from the rest of the world. Taking into account the citation data, though, it seems that the networks involved are much more global in nature, possibly reflecting their structure which has many random connections and which does not result in as wide a diffusion of knowledge as a small world structure. In this case North America does not have such a strong communication network. What it probably reflects, though, is the type of information being communicated, which is not an endogenous variable in the model of chapter I but which is an endogenous variable in the real world as is the identity of those who participate and form the networks. Tacit knowledge is by its knowledge more costly to communicate than codified knowledge and the data examined suggests that this cost feature of knowledge results in naturally occurring differences in the types of networks that exist. The data is consistent with tacit knowledge networks being small world in nature dictated by the interests of the agents, in this case mainly businesses, whereas the codified knowledge networks are more global with random connections where the connections are again dictated by the interests of the agents, in this case mainly academics and researchers.

II.3 Appendix A : data tables for newsgroups

Articles posted to Usenet newsgroup archives were examined for information flows about the Therac-25 event using the Google Groups search facility. Google has fully integrated the Usenet archives dating back to 1981 into Google Groups and offers access to more than 700 million articles. The specific newsgroups searched are: comp.risks, comp.software-eng, sci.med and all of the newsgroups under sci.med (31 in total), and sci.engr and all of the newsgroups under sci.engr (also 31 in total). Of the newsgroups under sci.med and sci.engr, four seem of particular relevance: sci.med.physics, sci.med.radiology, sci.engr.biomed, and sci.eng.safety. Articles posted in any language were investigated that mentioned the following words or phrases: “Therac-25”, “Therac”, “AECL”, “radiation”, “Leveson”, or “Theratron”. We were not able to find information about the starting date of the newsgroups, but the earliest date that we could find an article posted on comp.risks was 12 July, 1985, for comp.software-eng it was 18 April, 1985, for sci.med it was 16 October, 1986 (for sci.med.physics and sci.med.radiology it was 1 September, 1989 and 28 March, 1994, respectively), and for sci.engr it was 4 October, 1990 (for sci.engr.biomed and sci.eng.safety it was 8 February, 1992 and 28 March, 1995, respectively).

We could not find information about the number of individual articles posted in each newsgroup, but there is information about the number of “threads” in each newsgroup (these are more or less continuous chains of articles on single topics sharing common reference headers). Note that each thread consists of a minimum of one article and in some cases can consist of up to several hundred articles. Note also that the same article can be “cross-posted” to several newsgroups. No adjustment or allowance has been made for this feature on the basis that cross-postings still represent new sources of information to each of the different groups included. By 7 May, 2003, comp.software-eng had approximately 72,800 threads posted on it, sci.med. had approximately 199,000 threads posted on it and approximately 1.12 million threads for all twenty-three newsgroups under it (for sci.med.physics and sci.med.radiology it was 9,300 and 19,300 threads respectively), and sci.eng had 34,700 threads posted on it and 449,438 threads for all twenty-four newsgroups under it (for sci.engr.biomed and sci.engr.safety it was 12,400 and 13,000 threads respectively). Comp.risks is a moderated newsgroup (articles are sent to the moderator who edits and filters them, sometimes including comments of his own, and then posts the results) and instead of threads being posted on it, digests, or collections of edited and filtered articles, are periodically posted on it. By May, 2003, 1,910 digests had been posted on this newsgroup.

To give a crude idea about the numbers of articles per thread consider the months of January and February in 2003. During January, 87 threads were started in comp.software-eng comprising 478 articles and during February 88 threads were started comprising 1,459 articles. This gives an average of 11.1 articles per thread. During January, nine digests were posted to comp.risks comprising 115 articles in total and during February six digests were posted comprising 87 articles in total. This gives an average of 12.8 articles per digest. During January, 35 threads were started in sci.med.radiology comprising 109 articles and during February 17 articles were started comprising 23 articles. This gives an average of 2.5 articles per thread. For sci.engr.biomed the figures are 13 threads and 29 articles for January, 14 threads and 23 articles for February, and an average of 1.9 articles per thread.

The articles were classified using four dimensions: the month and year they were posted, the geographic location of the poster, the type of article posted, and the organisational affiliation of the poster. The geographic locations considered are North America (defined as the United States and Canada), Other English Speaking Countries (defined as Australia, New Zealand, the United Kingdom, and Ireland), Europe (excluding the United Kingdom and Ireland, and also not including Turkey and Russia), and All Other Countries. The affiliation of the poster is classified as Academic (universities and research institutes), Government, Commercial, and Other. The country of origin of the poster and their affiliation are derived from the email address used or failing this, the signature of the sender. Sometimes this information involved a further search of the internet to confirm or clarify matters. If the affiliation is not identifiable from this process then it is included in the Other category. Only one article, from a sci.med newsgroup, could not be classified using this system. Finally, articles are also defined as Personal (including personal correspondence and discussions between Usenet respondents) and Announcements (including announcements about conferences, course offerings, FAQs, and summaries of discussions, which are similar in nature to FAQs).

A detailed listing of the newsgroups examined is as follows:

comp.risks

comp.software-eng

sci.engr
sci.engr.advanced-tv
sci.engr.heat-vent-ac
sci.engr.analysis
sci.engr.biomed
sci.engr.chem
sci.engr.civil
sci.engr.coastal
sci.engr.color
sci.engr.control
sci.engr.electrical
sci.engr.electrical.compliance
sci.engr.electrical.sys-protection
sci.engr.geomechanics
sci.engr.joining
sci.engr.joining.misc
sci.engr.joining.welding
sci.engr.lighting
sci.engr.manufacturing
sci.engr.marine
sci.engr.marine.hydrodynamics
sci.engr.mech
sci.engr.metallurgy
sci.engr.micromachining
sci.engr.mining
sci.engr.radar+sonar
sci.engr.safety
sci.engr.semiconductors
sci.engr.surveying
sci.engr.television
sci.engr.television.advanced
sci.engr.television.broadcast

sci.med
sci.med.aids
sci.med.cannabis
sci.med.cardiology
sci.med.dentistry
sci.med.diseases
sci.med.diseases.als
sci.med.diseases.alzheimer
sci.med.diseases.cancer
sci.med.diseases.hepatitis
sci.med.diseases.lyme
sci.med.diseases.mult-sclerosis
sci.med.diseases.osteoporosis
sci.med.immunology
sci.med.informatics
sci.med.laboratory
sci.med.midwifery
sci.med.nursing
sci.med.nutrition
sci.med.obgyn
sci.med.occupational
sci.med.orthopedics
sci.med.pathology
sci.med.pharmacy
sci.med.physics
sci.med.prostate
sci.med.prostate.bph
sci.med.prostate.cancer
sci.med.prostate.prostatitis
sci.med.psychobiology
sci.med.radiology
sci.med.radiology.interventional

Table A1: Details of Articles from North American Posters to comp.risks

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of Total
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	1	0	0	0	1	1	0	0	3	7.3
1987	4	0	4	1	0	0	0	0	9	22.0
1988	1	0	0	0	0	0	0	0	1	2.4
1989	4	1	1	1	2	0	0	0	9	22.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	2	1	1	0	1	2	0	0	7	17.1
1992	2	0	0	1	1	0	0	0	4	9.8
1993	3	0	0	0	0	0	0	0	3	7.3
1994	0	0	0	0	0	0	0	0	0	0.0
1995	2	0	0	0	1	0	0	0	3	7.3
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	1	0	0	0	0	0	0	0	1	2.4
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	1	0	0	0	1	2.4
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	20	2	6	3	7	3	0	0	41	100.0
% of All	48.8	4.9	14.6	7.3	17.1	7.3	0.0	0.0	100.0	

Table A2: Details of Articles from Other English Speaking Posters to comp.risks

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of Total
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	1	0	0	0	0	0	0	0	1	25.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	2	0	0	0	0	0	0	0	2	50.0
1993	1	0	0	0	0	0	0	0	1	25.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	4	0	0	0	0	0	0	0	4	100.0
% of All	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table A3: Details of Articles from European Posters to comp.risks

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of Total
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	1	0	0	0	0	0	0	0	1	2.4
1989	1	0	0	0	0	0	0	0	1	2.4
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	2	0	0	0	0	0	0	0	2	4.9
% of All	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	

Table A4: Details of Articles from All Other Countries' Posters to comp.risks

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of Total
1985	0	0	0	0	0	0	0	0	0	na
1986	0	0	0	0	0	0	0	0	0	na
1987	0	0	0	0	0	0	0	0	0	na
1988	0	0	0	0	0	0	0	0	0	na
1989	0	0	0	0	0	0	0	0	0	na
1990	0	0	0	0	0	0	0	0	0	na
1991	0	0	0	0	0	0	0	0	0	na
1992	0	0	0	0	0	0	0	0	0	na
1993	0	0	0	0	0	0	0	0	0	na
1994	0	0	0	0	0	0	0	0	0	na
1995	0	0	0	0	0	0	0	0	0	na
1996	0	0	0	0	0	0	0	0	0	na
1997	0	0	0	0	0	0	0	0	0	na
1998	0	0	0	0	0	0	0	0	0	na
1999	0	0	0	0	0	0	0	0	0	na
2000	0	0	0	0	0	0	0	0	0	na
2001	0	0	0	0	0	0	0	0	0	na
2002	0	0	0	0	0	0	0	0	0	na
2003	0	0	0	0	0	0	0	0	0	na
Total	0	0	0	0	0	0	0	0	0	na
% of All	na	na	na	na	na	na	na	na	na	

Table A5: Geographic Area of Posters by Year for comp.risks

	NA	OE	EU	AO	Total	% of All
1985	0	0	0	0	0	0.0
1986	3	0	0	0	3	6.4
1987	9	0	0	0	9	19.1
1988	1	0	1	0	2	4.3
1989	9	0	1	0	10	21.3
1990	0	1	0	0	1	2.1
1991	7	0	0	0	7	14.9
1992	4	2	0	0	6	12.8
1993	3	1	0	0	4	8.5
1994	0	0	0	0	0	0.0
1995	3	0	0	0	3	6.4
1996	0	0	0	0	0	0.0
1997	0	0	0	0	0	0.0
1998	0	0	0	0	0	0.0
1999	1	0	0	0	1	2.1
2000	0	0	0	0	0	0.0
2001	1	0	0	0	1	2.1
2002	0	0	0	0	0	0.0
2003	0	0	0	0	0	0.0
Total	41	4	2	0	47	100.0
% of All	87.2	8.5	4.3	0.0	100.0	

Table A6: Affiliation of Article Posters by Year for comp.risks

	Acad.	Govt	Comm	Other
1985	0	0	0	0
1986	1	0	2	0
1987	4	5	0	0
1988	2	0	0	0
1989	6	2	2	0
1990	1	0	0	0
1991	3	1	3	0
1992	4	1	1	0
1993	4	0	0	0
1994	0	0	0	0
1995	2	0	1	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	1	0	0	0
2000	0	0	0	0
2001	0	0	1	0
2002	0	0	0	0
2003	0	0	0	0
Total	28	9	10	0
% of All	59.6	19.1	21.3	0.0

Table A7: Type of Article by Year for comp.risks

	Personal	Announce
1985	0	0
1986	2	1
1987	8	1
1988	2	0
1989	8	2
1990	1	0
1991	4	3
1992	5	1
1993	4	0
1994	0	0
1995	3	0
1996	0	0
1997	0	0
1998	0	0
1999	1	0
2000	0	0
2001	1	0
2002	0	0
2003	0	0
Total	39	8
% of All	83.0	17.0

Table A8: Number of Different Article Posters by Geographic Area for comp.risks

	No.	% of All Articles
NA	25	61.0
OE	3	75.0
EU	1	50.0
AO	na	na
World	29	61.7

Table A9: Details of Articles from North American Posters to comp.software-eng

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	1	0	0	0	0	0	0	1	1.0
1988	0	0	0	0	1	0	0	0	1	1.0
1989	2	1	0	0	1	1	0	0	5	5.0
1990	1	0	0	0	0	0	0	0	1	1.0
1991	1	3	0	0	0	0	0	0	4	4.0
1992	0	0	0	0	0	0	1	0	1	1.0
1993	5	1	0	0	13	0	3	0	22	21.8
1994	3	0	0	0	20	6	0	0	29	28.7
1995	0	2	0	1	4	3	0	0	10	9.9
1996	0	0	0	0	2	2	0	0	4	4.0
1997	4	0	0	0	2	0	0	0	6	5.9
1998	3	0	2	0	5	0	1	0	11	10.9
1999	2	0	0	0	0	0	2	0	4	4.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	1	0	0	0	1	1.0
2003	0	0	0	0	1	0	0	0	1	1.0
Total	21	8	2	1	50	12	7	0	101	100.0
% of All	20.8	7.9	2.0	1.0	49.5	11.9	6.9	0.0	100.0	

Table A10: Details of Articles from Other English Speaking Posters to comp.software-eng

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	1	0	0	0	0	0	0	0	1	33.3
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	1	0	1	33.3
1999	0	0	0	0	1	0	0	0	1	33.3
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	1	0	0	0	1	0	1	0	3	100.0
% of All	33.3	0.0	0.0	0.0	33.3	0.0	33.3	0.0	100.0	

Table A11: Details of Articles from European Posters to comp.software-eng

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	1	0	0	0	1	1.0
1996	0	0	0	0	1	0	0	0	1	1.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	0	0	0	0	2	0	0	0	2	2.0
% of All	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	2.0	

Table A12: Details of Articles from Other Countries' Posters to comp.software-eng

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	na
1986	0	0	0	0	0	0	0	0	0	na
1987	0	0	0	0	0	0	0	0	0	na
1988	0	0	0	0	0	0	0	0	0	na
1989	0	0	0	0	0	0	0	0	0	na
1990	0	0	0	0	0	0	0	0	0	na
1991	0	0	0	0	0	0	0	0	0	na
1992	0	0	0	0	0	0	0	0	0	na
1993	0	0	0	0	0	0	0	0	0	na
1994	0	0	0	0	0	0	0	0	0	na
1995	0	0	0	0	0	0	0	0	0	na
1996	0	0	0	0	0	0	0	0	0	na
1997	0	0	0	0	0	0	0	0	0	na
1998	0	0	0	0	0	0	0	0	0	na
1999	0	0	0	0	0	0	0	0	0	na
2000	0	0	0	0	0	0	0	0	0	na
2001	0	0	0	0	0	0	0	0	0	na
2002	0	0	0	0	0	0	0	0	0	na
2003	0	0	0	0	0	0	0	0	0	na
Total	0	0	0	0	0	0	0	0	0	na
% of All	na	na	na	na	na	na	na	na	na	

Table A13: Geographic Area of Posters by Year for comp.software-eng

	NA	OE	EU	AO	Total	% of All
1985	0	0	0	0	0	0.0
1986	0	0	0	0	0	0.0
1987	1	0	0	0	1	0.9
1988	1	0	0	0	1	0.9
1989	5	0	0	0	5	4.7
1990	1	0	0	0	1	0.9
1991	4	0	0	0	4	3.8
1992	1	0	0	0	1	0.9
1993	22	0	0	0	22	20.8
1994	29	1	0	0	30	28.3
1995	10	0	1	0	11	10.4
1996	4	0	1	0	5	4.7
1997	6	0	0	0	6	5.7
1998	11	1	0	0	12	11.3
1999	4	1	0	0	5	4.7
2000	0	0	0	0	0	0.0
2001	0	0	0	0	0	0.0
2002	1	0	0	0	1	0.9
2003	1	0	0	0	1	0.9
Total	101	3	2	0	106	100.0
% of All	95.3	2.8	1.9	0.0	100.0	

Table A14: Affiliation of Article Posters by Year for comp.software-eng

	Acad.	Govt	Comm	Other
1985	0	0	0	0
1986	0	0	0	0
1987	1	0	0	0
1988	0	0	1	0
1989	3	0	2	0
1990	1	0	0	0
1991	4	0	0	0
1992	0	0	0	1
1993	6	0	13	3
1994	4	0	26	0
1995	2	1	8	0
1996	0	0	5	0
1997	4	0	2	0
1998	3	2	5	2
1999	2	0	1	2
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	1	0
2003	0	0	1	0
Total	30	3	65	8
% of All	28.3	2.8	61.3	7.5

Table A15: Type of Article by Year for comp.software-eng

	Personal	Announce
1985	0	0
1986	0	0
1987	0	1
1988	1	0
1989	3	2
1990	1	0
1991	1	3
1992	1	0
1993	21	1
1994	24	6
1995	5	6
1996	3	2
1997	6	0
1998	12	0
1999	5	0
2000	0	0
2001	0	0
2002	1	0
2003	1	0
Total	85	21
% of All	80.2	19.8

Table A16: Number of Different Article Posters by Geographic Area for comp.software-eng

	No.	% of All Articles
NA	54	53.5
OE	3	100.0
EU	2	100.0
AO	na	na
World	59	55.7

Table A17: Details of Articles from North American Posters to sci.engr.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	3	3	0	0	6	20.0
1995	0	0	0	6	2	4	0	0	12	40.0
1996	0	0	0	0	5	4	0	0	9	30.0
1997	0	0	0	0	2	0	0	0	2	6.7
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	1	0	0	0	0	0	0	1	3.3
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	0	1	0	6	12	11	0	0	30	100.0
% of All	0.0	3.3	0.0	20.0	40.0	36.7	0.0	0.0	100.0	

Table A18: Details of Articles from Other English Speaking Posters to sci.engr.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	1	0	0	0	2	0	0	0	3	100.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	1	0	0	0	2	0	0	0	3	100.0
% of All	33.3	0.0	0.0	0.0	66.7	0.0	0.0	0.0	100.0	

Table A19: Details of Articles from European Posters to sci.engr.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	1	0	0	0	1	3.3
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	0	0	0	0	1	0	0	0	1	3.3
% of All	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	3.3	

Table A20: Details of Articles from All Other Countries' Posters to sci.engr.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	1	0	0	0	1	100.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	0	0	0	0	1	0	0	0	1	100.0
% of All	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0	

Table A21: Geographic Area of Posters by Year for sci.engr.*

	NA	OE	EU	AO	Total	% of All
1985	0	0	0	0	0	0.0
1986	0	0	0	0	0	0.0
1987	0	0	0	0	0	0.0
1988	0	0	0	0	0	0.0
1989	0	0	0	0	0	0.0
1990	0	0	0	0	0	0.0
1991	0	0	0	0	0	0.0
1992	0	0	0	0	0	0.0
1993	0	0	0	0	0	0.0
1994	6	0	0	0	6	17.1
1995	12	0	0	0	12	34.3
1996	9	0	0	0	9	25.7
1997	2	3	0	0	5	14.3
1998	0	0	0	0	0	0.0
1999	0	0	0	1	1	2.9
2000	1	0	1	0	2	5.7
2001	0	0	0	0	0	0.0
2002	0	0	0	0	0	0.0
2003	0	0	0	0	0	0.0
Total	30	3	1	1	35	100.0
% of All	85.7	8.6	2.9	2.9	100.0	

Table A22: Affiliation of Article Posters by Year for sci.engr.*

	Acad.	Govt	Comm	Other
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	0	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	6	0
1995	0	6	6	0
1996	0	0	9	0
1997	1	0	4	0
1998	0	0	0	0
1999	0	0	1	0
2000	1	0	1	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
Total	2	6	27	0
% of All	5.7	17.1	77.1	0.0

Table A23: Type of Article by Year for sci.engr.*

	Personal	Announce
1985	0	0
1986	0	0
1987	0	0
1988	0	0
1989	0	0
1990	0	0
1991	0	0
1992	0	0
1993	0	0
1994	3	3
1995	2	10
1996	5	4
1997	5	0
1998	0	0
1999	1	0
2000	1	1
2001	0	0
2002	0	0
2003	0	0
Total	17	18
% of All	48.6	51.4

Table A24: Number of Different Article Posters by Geographic Area for sci.engr.*

	No.	% of All Articles
NA	10	33.3
OE	3	100.0
EU	1	100.0
AO	1	100.0
World	15	42.9

Table A25: Details of Articles from North American Posters to sci.med.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	1	0	0	0	0	0	0	0	1	5.9
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	1	0	0	0	0	0	0	0	1	5.9
1993	1	0	0	0	0	0	0	0	1	5.9
1994	4	0	0	0	3	4	0	0	11	64.7
1995	1	0	0	0	0	0	0	0	1	5.9
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	1	0	0	0	1	5.9
1998	1	0	0	0	0	0	0	0	1	5.9
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	9	0	0	0	4	4	0	0	17	100.0
% of All	52.9	0.0	0.0	0.0	23.5	23.5	0.0	0.0	100.0	

Table A26: Details of Articles from Other English Speaking Posters to sci.med.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	2	0	0	0	0	0	0	0	2	100.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	2	0	0	0	0	0	0	0	2	100.0
% of All	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table A27: Details of Articles from European Posters to sci.med.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	1	0	0	0	0	0	0	0	1	5.9
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	1	0	0	0	0	0	0	0	1	5.9
% of All	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	

Table A28: Details of Articles from All Other Countries' Posters to sci.med.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	na
1986	0	0	0	0	0	0	0	0	0	na
1987	0	0	0	0	0	0	0	0	0	na
1988	0	0	0	0	0	0	0	0	0	na
1989	0	0	0	0	0	0	0	0	0	na
1990	0	0	0	0	0	0	0	0	0	na
1991	0	0	0	0	0	0	0	0	0	na
1992	0	0	0	0	0	0	0	0	0	na
1993	0	0	0	0	0	0	0	0	0	na
1994	0	0	0	0	0	0	0	0	0	na
1995	0	0	0	0	0	0	0	0	0	na
1996	0	0	0	0	0	0	0	0	0	na
1997	0	0	0	0	0	0	0	0	0	na
1998	0	0	0	0	0	0	0	0	0	na
1999	0	0	0	0	0	0	0	0	0	na
2000	0	0	0	0	0	0	0	0	0	na
2001	0	0	0	0	0	0	0	0	0	na
2002	0	0	0	0	0	0	0	0	0	na
2003	0	0	0	0	0	0	0	0	0	na
Total	0	0	0	0	0	0	0	0	0	na
% of All	na	na	na	na	na	na	na	na	na	

Table A29: Geographic Area of Posters by Year for sci.med.*

	NA	OE	EU	AO	Total	% of All
1985	0	0	0	0	0	0.0
1986	0	0	0	0	0	0.0
1987	0	0	0	0	0	0.0
1988	0	0	0	0	0	0.0
1989	1	0	0	0	1	5.0
1990	0	0	0	0	0	0.0
1991	0	0	0	0	0	0.0
1992	1	0	0	0	1	5.0
1993	1	0	0	0	1	5.0
1994	11	2	0	0	13	65.0
1995	1	0	0	0	1	5.0
1996	0	0	0	0	0	0.0
1997	1	0	0	0	1	5.0
1998	1	0	1	0	2	10.0
1999	0	0	0	0	0	0.0
2000	0	0	0	0	0	0.0
2001	0	0	0	0	0	0.0
2002	0	0	0	0	0	0.0
2003	0	0	0	0	0	0.0
Total	17	2	1	0	20	100.0
% of All	85.0	10.0	5.0	0.0	100.0	

Table A30: Affiliation of Article Posters by Year for sci.med.*

	Acad.	Govt	Comm	Other
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	1	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	1	0	0	0
1993	1	0	0	0
1994	6	0	7	0
1995	1	0	0	0
1996	0	0	0	0
1997	0	0	1	0
1998	2	0	0	0
1999	0	0	0	0
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
Total	12	0	8	0
% of All	60.0	0.0	40.0	0.0

Table A31: Type of Article by Year for sci.med.*

	Personal	Announce
1985	0	0
1986	0	0
1987	0	0
1988	0	0
1989	1	0
1990	0	0
1991	0	0
1992	1	0
1993	1	0
1994	9	4
1995	1	0
1996	0	0
1997	1	0
1998	2	0
1999	0	0
2000	0	0
2001	0	0
2002	0	0
2003	0	0
Total	16	4
% of All	80.0	20.0

Table A32: Number of Different Article Posters by Geographic Area for sci.med.*

	No.	% of All Articles
NA	11	64.7
OE	1	50.0
EU	1	100.0
AO	na	na
World	13	65.0

II.4 Appendix B : data tables on book citations

Journal citations of Nancy Leveson's 1995 book, *Safeware: System Safety and Computers*, were examined for information about how knowledge of the Therac-25 case diffused across countries, organisations, subjects, and over time. The details of the citing articles were collected from the Web of Science using the full search feature; this includes the expanded Science Citation Index, the Social Science Citation Index, and the Arts and Humanities Citation Index (all three indices range from 1995 until the present). All languages and all documents were allowed with searches specifyin Leveson as the cited author in conjunction with combinations of the significant words in the title as the cited work. Overall, 119 articles from the publication of the book in 1995 until May 2003 cited the book (see table B18). It is worth highlighting that the citations are only those of journal articles, excluding books and chapters in books, conference proceedings published as books or CD-ROMs, and the like.

The articles were classified using four dimensions: the year the citing article was published, the geographic location(s) of the authors of the citing article, the organisational affiliation(s) of the authors of the citing articles, and the main subject of the citing articles. The geographic locations considered are North America (defined as the United States and Canada), Other English Speaking Countries (defined as Australia, New Zealand, the United Kingdom, and Ireland), Europe (excluding the United Kingdom and Ireland, and also not including Turkey and Russia), and All Other Countries. The affiliation(s) of the authors is classified as Academic (universities and research institutes), Government, Commercial, and Other. The country(ies) of origin of the authors and their affiliation(s) are derived from the address(es) used. Sometimes this information involved a further search to confirm or clarify matters. If the affiliation is not identifiable from this process then it is included in the Other category. The details of all citing articles could be identified using this process. Authors who had multiple affiliations were classified as a single type if the affiliations were of the same type, or were treated as multiple authors if their affiliations were of different types. Equally, authors who were located in more than one geographic location were classified as a single types if the geographic locations were of the same type, or were treated as multiple authors if the geographic locations were of different types. The categories of subjects of the articles were computing, engineering (other than computer science or software engineering), medical, and other. Other is what is left over, typically management, ethics, and the like. In many cases the citing articles covered more than one area, but the main focus of the article was used to classify it along with information about the affiliation of the authors and the professional society (if one was involved) affiliated with the relevant journal in which the citing article was published. In determing how many distinct affiliations were associated with the citing articles, two approaches were used: defining affiliation by the name of the relevant organisation sub-unit (such as the university or company department) and defining affiliation by the name of the relevant organisation (such as the university or the company).

Three different methods are used to record information about the citing articles in an attempt to allow for multiple authors and multiple affiliation, since the aim of the exercise is to learn about diffusion of knowledge of the Therac-25 failure and any related learning. The first method focuses on the authors of each citing article (tables B1 to B8), the second method focuses on the affiliations of the authors of each citing article (tables B9 to B17), and the third method focuses on the subject of each citing article (tables B18 to B35. Note that this also means that the focus is on each citing article rather than worrying about multiple authors, affiliations, or both).

Table B1: Journal Citations of Leveson (1995) by Numbers of Citing North American Authors

	Academic				Government				Commercial				Other & Non-Ident.					
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Total	% of Total
1995									1								1	1.4
1996	2																2	2.8
1997	1								2	1							4	5.6
1998	7								3	3				1			14	19.7
1999	6	1			1				2	1			1				12	16.9
2000	7	6			1	1			4								19	26.8
2001		1									1						2	2.8
2002	3	4			1					3	1						12	16.9
2003			3								2						5	7.0
Total	26	12	3	0	3	1	0	0	12	8	4	0	1	1	0	0	71	100.0
%Tot	36.6	16.9	4.2	0.0	4.2	1.4	0.0	0.0	16.9	11.3	5.6	0.0	1.4	1.4	0.0	0.0	100.0	

Table B2: Journal Citations of Leveson (1995) by Numbers of Citing Other English Authors

	Academic				Government				Commercial				Other & Non-Ident.					
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Total	% of Total
1995																	0	0.0
1996	4																4	4.2
1997	2	3						1									6	6.3
1998	9	3	2		4												18	18.8
1999	13	8				1											22	22.9
2000	20	7		3			1										31	32.3
2001	1			3					5	1							10	10.4
2002	2	3															5	5.2
2003																	0	0.0
Total	51	24	2	6	4	1	1	1	5	1	0	0	0	0	0	0	96	100.0
%Tot	53.1	25.0	2.1	6.3	4.2	1.0	1.0	1.0	5.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B3: Journal Citations of Leveson (1995) by Numbers of Citing European (Excluding UK and Ireland) Authors

	Academic				Government				Commercial				Other & Non-Ident.					
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Total	% of Total
1995																	0	0.0
1996	7																7	10.9
1997		1								1							2	3.1
1998	4																4	6.3
1999	9				1				2								12	18.8
2000	8	2		5													15	23.4
2001	2	4		2						2							10	15.6
2002	1	2		3						2							8	12.5
2003	6																6	9.4
Total	37	9	0	10	1	0	0	0	2	5	0	0	0	0	0	0	64	100.0
%Tot	57.8	14.1	0.0	15.6	1.6	0.0	0.0	0.0	3.1	7.8	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B4: Journal Citations of Leveson (1995) by Numbers of Citing All Other Countries Authors

	Academic				Government				Commercial				Other & Non-Ident.					
	Com	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Total**	**% of Total**
1995																	0	0.0
1996																	0	0.0
1997	4	2															6	17.6
1998	2	9							1								12	35.3
1999										3							3	8.8
2000	5																5	14.7
2001																	0	0.0
2002				1						1							2	5.9
2003	4	2															6	17.6
Total	15	13	0	1	0	0	0	0	1	4	0	0	0	0	0	0	34	100.0
%Tot	44.1	38.2	0.0	2.9	0.0	0.0	0.0	0.0	2.9	11.8	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B5: Geographic Areas of Journal Citations of Leveson (1995) by Numbers of Citing Authors

	NA	**OE**	**EU**	**AO**	**Total**	**% of Total**
1995	1				1	0.4
1996	2	4	7		13	4.9
1997	4	6	2	6	18	6.8
1998	14	18	4	12	48	18.1
1999	12	22	12	3	49	18.5
2000	19	31	15	5	70	26.4
2001	2	10	10		22	8.3
2002	12	5	8	2	27	10.2
2003	5		6	6	17	6.4
Total	71	96	64	34	265	100.0
%Tot	26.8	36.2	24.2	12.8	100.0	

Table B6: Affiliations of Journal Citations of Leveson (1995) by Numbers of Citing Authors

	Acad	**Govt**	**Comm**	**Other**	**Total**	**% of Total**
1995			1		1	0.4
1996	13				13	4.9
1997	13	1	4		18	6.8
1998	36	4	7	1	48	18.1
1999	37	3	8	1	49	18.5
2000	63	3	4		70	26.4
2001	13		9		22	8.3
2002	19	1	7		27	10.2
2003	15		2		17	6.4
Total	209	12	42	2	265	100.0
%Tot	78.9	4.5	15.8	0.8	100.0	

Table B7: Subject Areas of Journal Citations of Leveson (1995) by Numbers of Citing Authors

	Com	Eng	Med	Oth	Total	% of Total
1995	1				1	0.4
1996	13				13	4.9
1997	9	8		1	18	6.8
1998	30	16	2		48	18.1
1999	35	14			49	18.5
2000	45	16	1	8	70	26.4
2001	8	8	1	5	22	8.3
2002	7	15	1	4	27	10.2
2003	10	2	5		17	6.4
Total	158	79	10	18	265	100.0
%Tot	59.6	29.8	3.8	6.8	100.0	

Table B8: Number of Different Authors Citing Leveson (1995) by Geographic Area

	Number of Citing Articles Authored Per Author					Percentage of Grand Total				
	1	**2**	**3**	**>3**	**Total**	**1**	**2**	**3**	**>3**	**Total**
NA	60	7	3	1	71	26.8	3.1	1.3	0.4	31.7
OE	60	8	0	1	69	26.8	3.6	0.0	0.4	30.8
EU	42	11	0	0	53	18.8	4.9	0.0	0.0	23.7
AO	29	2	0	0	31	12.9	0.9	0.0	0.0	13.8
Total	191	28	3	2	224	85.3	12.5	1.3	0.9	100.0

Table B9: Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing North American Authors

	Academic				Government				Commercial				Other & Non-Ident.					
	Com	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Total**	**% of Total**
1995									1								1	1.5
1996	2																2	3.0
1997	2	1							1	1							5	7.6
1998	4	1	1		2				3	2				1			14	21.2
1999	7	1							1	2			1				12	18.2
2000	6	4			1	1			4								16	24.2
2001		1									1						2	3.0
2002	2	3			1					3	1						10	15.2
2003			2								2						4	6.1
Total	23	11	3	0	4	1	0	0	10	8	4	0	1	1	0	0	66	100.0
%Tot	34.8	16.7	4.5	0.0	6.1	1.5	0.0	0.0	15.2	12.1	6.1	0.0	1.5	1.5	0.0	0.0	100.0	

Table B10: Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing Other English Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth		
1995																	0	0.0
1996	3																3	6.3
1997	1	1								1							3	6.3
1998	6	1	1														8	16.7
1999	4	3				1											8	16.7
2000	8	4		2					1								15	31.3
2001	1			3							1	1					6	12.5
2002	3	2															5	10.4
2003																	0	0.0
Total	26	11	1	5	0	1	0	0	1	1	1	1	0	0	0	0	48	100.0
%Tot	54.2	22.9	2.1	10.4	0.0	2.1	0.0	0.0	2.1	2.1	2.1	2.1	0.0	0.0	0.0	0.0	100.0	

Table B11: Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing European (excluding UK and Ireland) Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth		
1995																	0	0.0
1996	2																2	5.3
1997										1							1	2.6
1998	3																3	7.9
1999	5				1				1								7	18.4
2000	5	1		5													11	28.9
2001	1	2		1						1							5	13.2
2002	1	2		1						2							8	15.8
2003	3																3	7.9
Total	20	5	0	7	1	0	0	0	1	4	0	0	0	0	0	0	38	100.0
%Tot	52.6	13.2	0.0	18.4	2.6	0.0	0.0	0.0	2.6	10.5	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B12: Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing All Other Countries Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth		
1995																	0	0.0
1996																	0	0.0
1997	2	2															4	21.1
1998	2	1							1								4	21.1
1999		1								1							2	10.5
2000	4																4	21.1
2001										1							1	5.3
2002				1													1	5.3
2003	2	1															3	15.8
Total	10	5	0	1	0	0	0	0	1	2	0	0	0	0	0	0	19	100.0
%Tot	52.6	26.3	0.0	5.3	0.0	0.0	0.0	0.0	5.3	10.5	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B13: Geographic Areas of Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing Authors

	NA	OE	EU	AO	Total	% of Total
1995	1				1	0.6
1996	2	3	2		7	4.1
1997	5	3	1	4	13	7.6
1998	14	8	3	4	29	17.0
1999	12	8	7	2	29	17.0
2000	16	15	11	4	46	26.9
2001	2	6	5	1	14	8.2
2002	10	5	6	1	22	12.9
2003	4		3	3	10	5.8
Total	66	48	38	19	171	100.0
%Tot	38.6	28.1	22.2	11.1	100.0	

Table B14: Affiliations of Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing Authors

	Acad	Govt	Comm	Other	Total	% of Total
1995			1		1	0.6
1996	7				7	4.1
1997	9		4		13	7.6
1998	20	2	6	1	29	17.0
1999	21	2	5	1	29	17.0
2000	39	2	5		46	26.9
2001	9		5		14	8.2
2002	15	1	6		22	12.9
2003	8		2		10	5.8
Total	128	7	34	2	171	100.0
%Tot	74.9	4.1	19.9	1.2	100.0	

Table B15: Subject Areas of Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing Authors

	Comp	Eng	Med	Oth	Total	% of Total
1995	1				1	0.6
1996	7				7	4.1
1997	6	7			13	7.6
1998	21	6	2		29	17.0
1999	20	9			29	17.0
2000	29	10		7	46	26.9
2001	2	5	2	5	14	8.2
2002	7	12	1	2	22	12.9
2003	5	1	4		10	5.8
Total	98	50	9	14	171	100.0
%Tot	57.3	29.2	5.3	8.2	100.0	

Table B16: Number of Different Organisational Affiliations of Authors Citing Leveson (1995) by Geographic Area (with Affiliation Equalling Organisational Sub-Unit)

	Number of Citing Articles Per Organisation					Percentage of Grand Total				
	1	**2**	**3**	**>3**	**Total**	**1**	**2**	**3**	**>3**	**Total**
NA	46	9	2		57	32.6	6.4	1.4		40.4
OE	23	6	2	1	32	16.3	4.3	1.4	0.7	22.7
EU	27	7			34	19.1	5.0			24.1
AO	17	1			18	12.1	0.7			12.8
Total	113	23	4	1	141	80.1	16.3	2.8	0.7	100.0

Table B17: Number of Different Organisational Affiliations of Authors Citing Leveson (1995) by Geographic Area (with Affiliation Equalling the Overall Organisational)

	Number of Citing Articles Per Organisation					Percentage of Grand Total				
	1	**2**	**3**	**>3**	**Total**	**1**	**2**	**3**	**>3**	**Total**
NA	36	9	2	1	48	30.3	7.6	1.7		40.3
OE	18	5	3	2	28	15.1	4.2	2.5	1.7	23.5
EU	24	6	1		31	20.2	5.0			26.1
AO	7	4	1		12	5.9	3.4			10.1
Total	85	24	7	3	119	71.4	20.2	4.2	1.7	100.0

Table B18: Number of Articles Citing Leveson (1995) by Subject of the Citing Articles

	Com	Eng	Med	Other	Total	% of Total
1995	1				1	0.8
1996	4				4	3.4
1997	5	5			10	8.4
1998	10	4	2		16	13.4
1999	17	7			24	20.2
2000	19	7		5	31	26.1
2001	2	4	2	3	11	9.2
2002	6	7	1	2	16	13.4
2003	3	1	2		6	5.0
Total	67	35	7	10	119	100.0
%Tot	56.3	29.4	5.9	8.4	100.0	

Table B19: Number of Citations of Articles Citing Leveson (1995) by Subject of the Citing Articles

	Com	Eng	Med	Other	Total	% of Total
1995						0.0
1996	33				33	22.4
1997	6	27			33	22.4
1998	25	4	3		32	21.8
1999	18	1			19	12.9
2000	13	8		5	26	17.7
2001	1				1	0.7
2002	1	1	1		3	2.0
2003					0	0.0
Total	97	41	4	5	147	100.0
%Tot	66.0	27.9	2.7	3.4	100.0	

Table B20: Average Number of Citations of Articles Citing Leveson (1995) by Subject of the Citing Articles

	Com	Eng	Med	Other	Total
1995	0.00	na	na	na	0.00
1996	8.25	na	na	na	8.25
1997	1.20	5.40	na	na	6.60
1998	2.50	1.00	1.50	na	5.00
1999	1.06	0.14	na	na	1.20
2000	0.68	1.14	na	1.00	2.83
2001	0.50	0.00	0.00	0.00	0.50
2002	0.17	0.14	1.00	0.00	1.31
2003	0.00	0.00	0.00	na	0.00
Total	1.45	1.17	0.57	0.50	1.24

Table B21: Number of Authors Per Computing Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995		1			1	0.0	1.5	0.0	0.0	1.5
1996		3		1	4	0.0	4.5	0.0	1.5	6.0
1997	1	3	1		5	1.5	4.5	1.5	0.0	7.5
1998	3	2	2	3	10	4.5	3.0	3.0	4.5	14.9
1999	7	7	1	2	17	10.4	10.4	1.5	3.0	25.4
2000	6	5	5	3	19	9.0	7.5	7.5	4.5	28.4
2001	1	1			2	1.5	1.5	0.0	0.0	3.0
2002	4	2			6	6.0	3.0	0.0	0.0	9.0
2003		1		2	3	0.0	1.5	0.0	3.0	4.5
Total	22	25	9	11	67	32.8	37.3	13.4	16.4	100.0

Table B22: Number of Authors Per Engineering Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997	2	2	1		5	5.7	5.7	2.9	0.0	14.3
1998	1	1		2	4	2.9	2.9	0.0	5.7	11.4
1999	4		2	1	7	11.4	0.0	5.7	2.9	20.0
2000	2	2	2	1	7	5.7	5.7	5.7	2.9	20.0
2001	2	1	1		4	5.7	2.9	2.9	0.0	11.4
2002	2	3	1	1	7	5.7	8.6	2.9	2.9	20.0
2003		1			1	0.0	2.9	0.0	0.0	2.9
Total	13	10	7	5	35	37.1	28.6	20.0	14.3	100.0

Table B23: Number of Authors Per Medical Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997					0	0.0	0.0	0.0	0.0	0.0
1998	2				2	28.6	0.0	0.0	0.0	28.6
1999					0	0.0	0.0	0.0	0.0	0.0
2000					0	0.0	0.0	0.0	0.0	0.0
2001	1			1	2	14.3	0.0	0.0	14.3	28.6
2002	1				1	14.3	0.0	0.0	0.0	14.3
2003		1	1		2	0.0	14.3	14.3	0.0	28.6
Total	4	1	1	1	7	57.1	14.3	14.3	14.3	100.0

Table B24: Number of Authors Per Other Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997					0	0.0	0.0	0.0	0.0	0.0
1998					0	0.0	0.0	0.0	0.0	0.0
1999					0	0.0	0.0	0.0	0.0	0.0
2000	3	1	1		5	30.0	10.0	10.0	0.0	50.0
2001	1	2			3	10.0	20.0	0.0	0.0	30.0
2002	1		1		2	10.0	0.0	10.0	0.0	20.0
2003					0	0.0	0.0	0.0	0.0	0.0
Total	5	3	2	0	10	50.0	30.0	20.0	0.0	100.0

Table B25: Number of Authors Per Article Citing Leveson (1995) for All Subjects

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995		1			1	0.0	0.8	0.0	0.0	0.8
1996		3		1	4	0.0	2.5	0.0	0.8	3.4
1997	3	5	2		10	2.5	4.2	1.7	0.0	8.4
1998	6	3	2	5	16	5.0	2.5	1.7	4.2	13.4
1999	11	7	3	3	24	9.2	5.9	2.5	2.5	20.2
2000	11	8	8	4	31	9.2	6.7	6.7	3.4	26.1
2001	5	4	1	1	11	4.2	3.4	0.8	0.8	9.2
2002	8	5	2	1	16	6.7	4.2	1.7	0.8	13.4
2003		3	1	2	6	0.0	2.5	0.8	1.7	5.0
Total	44	39	19	17	119	37.0	32.8	16.0	14.3	100.0

Table B26: Number of Affiliations Per Computing Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995	1				1	1.5	0.0	0.0	0.0	1.5
1996	1	3			4	1.5	4.5	0.0	0.0	6.0
1997	4	1			5	6.0	1.5	0.0	0.0	7.5
1998	3	5		2	10	4.5	7.5	0.0	3.0	14.9
1999	14	3			17	20.9	4.5	0.0	0.0	25.4
2000	12	5	1	1	19	17.9	7.5	1.5	1.5	28.4
2001	2				2	3.0	0.0	0.0	0.0	3.0
2002	5	1			6	7.5	1.5	0.0	0.0	9.0
2003	1	2			3	1.5	3.0	0.0	0.0	4.5
Total	43	20	1	3	67	64.2	29.9	1.5	4.5	100.0

Table B27: Number of Affiliations Per Engineering Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997	2	3			5	5.7	8.6	0.0	0.0	14.3
1998	3		1		4	8.6	0.0	2.9	0.0	11.4
1999	5	1	1		7	14.3	2.9	2.9	0.0	20.0
2000	4	3			7	11.4	8.6	0.0	0.0	20.0
2001	3		1		4	8.6	0.0	2.9	0.0	11.4
2002	4	1	1	1	7	11.4	2.9	2.9	2.9	20.0
2003	1				1	2.9	0.0	0.0	0.0	2.9
Total	22	8	4	1	35	62.9	22.9	11.4	2.9	100.0

Table B28: Number of Affiliations Per Medical Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997					0	0.0	0.0	0.0	0.0	0.0
1998	2				2	28.6	0.0	0.0	0.0	28.6
1999					0	0.0	0.0	0.0	0.0	0.0
2000					0	0.0	0.0	0.0	0.0	0.0
2001	2				2	28.6	0.0	0.0	0.0	28.6
2002	1				1	14.3	0.0	0.0	0.0	14.3
2003		2			2	0.0	28.6	0.0	0.0	28.6
Total	5	2	0	0	7	71.4	28.6	0.0	0.0	100.0

Table B29: Number of Affiliations Per Other Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997					0	0.0	0.0	0.0	0.0	0.0
1998					0	0.0	0.0	0.0	0.0	0.0
1999					0	0.0	0.0	0.0	0.0	0.0
2000	4		1		5	40.0	0.0	10.0	0.0	50.0
2001	1	1	1		3	10.0	10.0	10.0	0.0	30.0
2002	2				2	20.0	0.0	0.0	0.0	20.0
2003					0	0.0	0.0	0.0	0.0	0.0
Total	7	1	2	0	10	70.0	10.0	20.0	0.0	100.0

Table B30: Number of Affiliations Per Article Citing Leveson (1995) for All Subjects

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995	1				1	0.8	0.0	0.0	0.0	0.8
1996	1	3			4	0.8	2.5	0.0	0.0	3.4
1997	6	4			10	5.0	3.4	0.0	0.0	8.4
1998	8	5	1	2	16	6.7	4.2	0.8	1.7	13.4
1999	19	4	1		24	16.0	3.4	0.8	0.0	20.2
2000	20	8	2	1	31	16.8	6.7	1.7	0.8	26.1
2001	8	1	2		11	6.7	0.8	1.7	0.0	9.2
2002	12	2	1	1	16	10.1	1.7	0.8	0.8	13.4
2003	2	4			6	1.7	3.4	0.0	0.0	5.0
Total	77	31	7	4	119	64.7	26.1	5.9	3.4	100.0

Table B31: Number of Countries by Affiliations Per Computing Article Citing Leveson (1995)

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995	1				1	1.5				1.5				0				0.0
1996	4				4	6.0				6.0				0				0.0
1997	5				5	7.5				7.5				0				0.0
1998	7	3			10	10.4	4.5			14.9	3			3	4.5			4.5
1999	17				17	25.4				25.4				0				0.0
2000	16	2	1		19	23.9	3.0	1.5		28.4	2	1		3	3.0	1.5		4.5
2001	2				2	3.0				3.0				0				0.0
2002	6				6	9.0				9.0				0				0.0
2003	3				3	4.5				4.5				0				0.0
Total	61	5	1	0	67	91.0	7.5	1.5	0.0	100.0	5	1	0	6	7.5	1.5	0.0	9.0

Table B32: Number of Countries by Affiliations Per Engineering Article Citing Leveson (1995)

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995					0					0.0				0				0.0
1996					0					0.0				0				0.0
1997	4	1			5	11.4	2.9			14.3		1		1		2.9		2.9
1998	4				4	11.4				11.4				0				0.0
1999	7				7	20.0				20.0				0				0.0
2000	7				7	20.0				20.0				0				0.0
2001	4				4	11.4				11.4				0				0.0
2002	5	2			7	14.3	5.7			20.0	1	1		2	2.9	2.9		5.7
2003	1				1	2.9				2.9				0				0.0
Total	32	3	0	0	35	91.4	8.6	0.0	0.0	100.0	1	2	0	3	2.9	5.7	0.0	8.6

Table B33: Number of Countries by Affiliations Per Medical Article Citing Leveson (1995)

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995					0					0.0				0				0.0
1996					0					0.0				0				0.0
1997					0					0.0				0				0.0
1998	2				2	28.6				28.6				0				0.0
1999					0					0.0				0				0.0
2000					0					0.0				0				0.0
2001	2				2	28.6				28.6				0				0.0
2002	1				1	14.3				14.3				0				0.0
2003	1	1			2	14.3	14.3			28.6		1		1		14.3		14.3
Total	6	1	0	0	7	85.7	14.3	0.0	0.0	100.0	0	1	0	1	0.0	14.3	0.0	14.3

Table B34: Number of Countries by Affiliations Per Medical Article Citing Leveson (1995)

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995					0					0.0				0				0.0
1996					0					0.0				0				0.0
1997					0					0.0				0				0.0
1998					0					0.0				0				0.0
1999					0					0.0				0				0.0
2000	4	1			5	40.0	10.0			50.0			1	1			10.0	10.0
2001	3				3	30.0				30.0				0				0.0
2002	2				2	20.0				20.0				0				0.0
2003					0					0.0				0				0.0
Total	9	1	0	0	10	90.0	10.0	0.0	0.0	100.0	0	0	1	1	0.0	0.0	10.0	10.0

Table B35: Number of Countries by Affiliations Per Article Citing Leveson (1995) for All Subjects

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995	1				1	0.8				0.8				0				0.0
1996	4				4	3.4				3.4				0				0.0
1997	9	1			10	7.6	0.8			8.4		1		1		0.8		1.5
1998	13	3			16	10.9	2.5			13.4	3			3	2.5			4.5
1999	24				24	20.2				20.2				0				0.0
2000	27	3	1		31	22.7	2.5	0.8		26.1	2	1	1	4	1.7	0.8	0.8	6.0
2001	11				11	9.2				9.2				0				0.0
2002	14	2			16	11.8	1.7			13.4	1	1		2	0.8	0.8		3.0
2003	5	1			6	4.2	0.8			5.0		1		1		0.8		1.5
Total	108	10	1	0	119	90.8	8.4	0.8	0.0	100.0	6	4	1	11	5.0	3.4	0.8	9.2

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Chapter 4

Determining the optimal number of prototype systems
in commercializing new risky technologies

IV.1 Introduction

This contribution discusses a model in which an industrial planner invests in an optimal number of technologies during the prototype (demonstration) phase of a long-term technology development program.[1] The model examines the trade-off between (1) "learning-by-doing" in the construction of prototypes, (2) "learning-by-using" in operating new technologies to increase the probability of discovering the least cost design, and (3) the probability of discovering a "fatal flaw" in the demonstrated prototypes.

Although this model is applied to nuclear energy systems, it is applicable to many technology-intensive, hazardous industries, including the chemical and petrochemical industries. In all of these industries a central planner, either a government agency or industrial consortium, attempts to development new, safer technologies that are economically competitive with existing technologies. The planner's problem is to minimize the cost of developing the new technology subject to a safety constraint. This paper examines the how learning-by-doing in construction, learning-by-using in operation, and the discovery that a particular technology does not satisfy the safety constraint influences the optimal number of costly prototype systems to fund.

IV.2 Commercializing New Nuclear Energy Technologies

To provide a context for the modeling of optimal prototype selection, consider the Generation IV international initiative to maximize the probability of commercializing a new nuclear energy system by 2025, when many of the currently operating nuclear power plants will be retired. See http//gif.inel.gov/roadmap. Ten countries are participating in the Generation IV International Forum (GIF): Argentina, Brazil, Canada, France, Japan, the Republic of Korea, the Republic of South Africa, Switzerland, the United Kingdom, and the United States. During 2000 and 2001, over 100 experts evaluated nearly 100 candidate technologies using multi-attribute decision-making techniques. These attributes were based on the goals for Generation IV nuclear energy systems (see GIF 2002):

- **Economics–1:** Generation IV nuclear energy systems will have a clear life-cycle cost advantage over other energy sources.
- **Economics–2:** Generation IV nuclear energy systems will have a level of financial risk comparable to other energy projects.
- **Sustainability–1:** Generation IV nuclear energy systems will provide sustainable energy generation that meets clean air objectives and promotes long-term availability of systems and effective fuel utilization for worldwide energy production.
- **Sustainability–2:** Generation IV nuclear energy systems will minimize and manage their nuclear waste and notably reduce the long-term stewardship burden, thereby improving protection for the public health and the environment.

- **Safety and Reliability–1:** Generation IV nuclear energy systems operations will excel in safety and reliability.
- **Safety and Reliability–2:** Generation IV nuclear energy systems will have a very low likelihood and degree of reactor core damage.
- **Safety and Reliability–3:** Generation IV nuclear energy systems will eliminate the need for offsite emergency response.
- **Proliferation Resistance and Physical Protection–1:** Generation IV nuclear energy systems will increase the assurance that they are a very unattractive and the least desirable route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism.

In 2002 six technologies were selected for three missions. These missions are electricity generation, hydrogen production, and actinide (spent nuclear fuel) management. The selected technologies are (1) the Supercritical-Water-Cooled Reactor (SCWR), (2) the Very-High-Temperature (Gas-Graphite) Reactor (VHTR), (3) the Gas-Cooled Fast Reactor (GFR), (4) the Sodium-Cooled Fast Reactor (SFR), (5) the Lead-Cooled Fast Reactor (LFR), and (6) the Molten Salt Reactor (MSR). By 2003 design teams had been formed to develop the first four technologies.

During the next 20 years, these technologies will undergo four phases of development:
(1) a **viability** phase to resolve key feasibility and proof-of-principle issues;
(2) a **performance** phase in which systems (reactor, energy conversion, and fuel cycle facilities) are designed and licensed;
(3) a **demonstration** (or prototype) phase in which key systems are constructed to optimize safety and economics; and
(4) a **deployment** (or commercialization) phase in which standardized nuclear energy systems are built in GIF countries and exported to international markets.

Demonstrating a entire new nuclear energy system, including reactors, energy conversion systems, fuel fabrication facilities, and spent fuel management systems (including reprocessing) could cost billions of dollars. Therefore, to maximize the expected net present value of developing, demonstrating, and deploying a fleet of new nuclear plants, how many technologies should be demonstrated before picking one for commercialization? Although the demonstration phase may not begin for a dozen years, the optimal number of technologies to demonstrate has implications for the (down) selection of technologies at the end of the viability phase, which could take place within 4 years (by 2007).

IV.3. Demonstration of New Technologies

The industrial planner's goal is to maximize the net present value of building and operating a new technology system. Because of the high cost of prototypes and commercial plants (compared to research and development), the problem can be simplified by focusing on the demonstration and deployment phases of the program.[2]

In the first stage of the demonstration phase *N* plants are built, for example, 1000 megawatts (MW) of the six (N = 6) different Generation IV technologies. In the second stage these plants are operated to discover the least cost method of production. Also, operation gives the planner an opportunity to discover design flaws in the new system(s). In the deployment phase, one technology type is selected and *X* sets of *N* plants are constructed. How many prototype systems should be built in Stage 1 of the demonstration phase?

IV.3.1. Demonstration

IV.3.1.1. Demonstration – Stage 1: Construction and Learning-by-Doing

In Stage 1 a total of *N* plants (units) are built with *M* technologies; there are *n* units of each type, so $N = n \cdot M$. [3] If the total number of units (N) is given exogenously (e.g., by market demand), the planner's problem can be characterized as either choosing the optimal number of technology types (M) or, equivalently, choosing the optimal level of diversity, where diversity, *d*, can be measured as (M / N). The planner can choose a level of diversity between (1) no diversity (complete standardization), where $d = 1/N$ (e.g., 6,000 MW of one technology), and (2) complete diversity, where $d = 1$ (e.g., 1,000 MW of each technology).

To determine the optimal level of diversity, assume that (1) there is an equal number of units of all types $n_j = n$, where $j = 1, \ldots, M$ (this implies they are all the same size), and (2) first-of-a-kind (overnight) construction costs, *k* (e.g., in dollars per net megawatt-electric, MW) are the same for each type ($k_j = k$ for all *j*). (Because all costs are discounted to the beginning of Stage 1, financing costs, e.g., Interest During Construction, are not included). For example, *k* equals $1,250 per net kW. Further, assume all technology types (units) are built *simultaneously* during Stage 1 of τ years, e.g., $\tau = 4$ years.[4]

Here, learning-by-doing during construction is similar to economies of scale in the number of units, so :

$$k_n = k\, n^{-\gamma}, \quad 0 < \gamma \leq 1 , \tag{1}$$

where k_n is the overnight construction cost per MW for *n* units of a single type and γ is a measure of learning. For an example, see Table 2. The total cost of units for each technology is

$$n\, W\, k_n = n\, W\, k\, n^{-\gamma} = W\, k\, n^{1-\gamma}, \tag{2}$$

where *W* is the size of each unit in MW. The total cost (K) of building all *M* technologies of *n* units apiece is

$$K = M\,(W\, k\, n^{1-\gamma}) = M\, W\, k\, (N/M)^{1-\gamma} = N\, W\, k\, (M/N)^{\gamma} = N\, W\, k\, d^{\gamma} . \tag{3}$$

For example, with complete diversity for a program of six different 1,000 (net) MW units with prototype costs of $1,250/kW is K = $7.5 billion (B). Under complete standardization with γ = 0.05, learning-by-doing in the construction of six plants of the same technology reduces *k* to $1,143 and K = $6.86B. See Table 2.

IV.3.1.2. Demonstration – Stage 2: Operations and Learning-by-Using

In Stage 2 of the demonstration phase, the focus is on learning-by-using to minimize the cost of generating electricity at units built in Stage 1.[5] The annual operating cost (C_2, in dollars per MWh) can be decomposed into (1) an initial cost (c) minus (2) a cost saving (cs_j , where j indexes the technology). Assume that initial operations cost is equal to an average c for all types. For example, $18/MWh for a nuclear electricity system with fuel costs (e.g., $6/MWh), operations and maintenance (primarily labor) costs (e.g., $9/MWh), capital additions (primarily replacement equipment) (e.g., $2/MWh), and administrative costs (*e.g*., $1/MWh).

The cost savings component cs_j varies with differences in learning-by-using. It is a function of the number of units constructed of each type. Operation yields learning opportunities that generate a distribution of attainable cost savings. A larger number of units of a particular technology type leads to more experience and to an increase in the probability of discovering the *least cost* method of producing electricity: $\partial F(cs_j)/\partial n > 0$, where $F(cs_j)$ is the cumulative distribution function of attaining the *maximum* cost savings for each technology.

If cost savings, cs_j, are distributed with mean μ_j and variance σ_j^2, the expected *maximum* cost savings for units of type j is $E(cs_j^{\max} \mid n)$. Making use of a general result regarding extreme value distributions, the expected extreme value ($cs_j^{\max}$) is a positive function of the mean and the standard deviation, when such samples are drawn from a unimodal distribution (see Gumbel 1958). Also, with an extreme value distribution the standard deviation increases with the sample size (n). The expected maximum cost savings from learning-by-using for *each* technology can be modeled as

$$E\,(cs^{\max} \mid n) = \sigma\,(\log n)\,, \text{ for } \; n \geq 1 \;. \tag{4}$$

(Assume the mean cost savings, μ_j, is absorbed into c). Then the annual cost and realized cost savings in Stage 2 are

$$C_2 = c - cs = c - \mu - \sigma \log n = c - \sigma \log (N/M)$$
$$= c - \sigma(-\log (M/N)) = c + \sigma \log d\,, \quad \text{where } d \leq 1 \,.$$
(5)

For N units of capacity W the total operations cost per year (TC_2) is $N\,W\,C_2\,h$, where h is the hours per year, usually 8,760. For example, c = $18/MWh and σ = $1/MWh, with complete diversity, d = 1, *log* d = 0, cs = 0, and C_2 = $18/MWh. With complete standardization, d = 0.167, log d = –1.79, cs = –1.79, C_2 = $16.21/MWh. See Table 2.

IV.3.1.3. The Price of Electricity and Net Present Value

During Stage 2 and during their lifetimes (τ_2 years, assumed to be 40 years), the power plants will be selling electricity (or an equivalent energy product, such as hydrogen). Revenues will be equal to $P\,N\,W\,CF\,h$, where P is the price of electricity (e.g., P = $35/MWh) and CF is the average lifetime capacity factor (e.g., CF = 90%). Discounted total costs must be compared with discounted total revenues. Net revenues are discounted over the plant's lifetime to the beginning of Stage 2 with a uniform series, present value factor, δ_2 , which depends on the cost of capital, r (assumed to be 7% real, or about 10% nominal) and the life of the nuclear unit, τ_2. Also, $\delta_1 = (1 + r)^{-t}$ discounts these costs to the beginning of Stage 1. The Net Present Value (NPV) of plants at the beginning of Stage 1 built in Stage 2 and operated for 40 years is

$$NPV_1 \;\; = N\,W\,\{\delta_1\;\delta_2\,h\,[\,P\cdot CF \;-\; c - \sigma\;\log d\;\;]\;-\;k\,d^{\gamma}\}. \qquad (6)$$

The NPV_1 of the project is \$1.24B with total standardization and –\$0.35B with complete diversity. *Standardization is cheaper than diversity.* With a cost of capital of 7%, the NPV could be negative under the parameters assumed here, i.e., to implement this project, the industrial planner might have to subsidize prototype construction during the demonstration phase.

IV.3.1.4. Learning about a "Fatal Flaw"

One of the benefits of diversity is the ability to hedge against discovering a "fatal flaw" in technologies built during the demonstration phase. (This should not be interpreted as uncertainty in construction or operating cost.) The fatal flaw is the inability of a new technology to satisfy some non-economic criteria imposed by the central planner, such as a safety problem or a public acceptance (e.g., non-proliferation) issue. For example, in the case of Generation IV this could involve any of the criteria associated with safety or proliferation resistance, see Section 1, above. The new technology either meets a criterion or it does not. If it does not, it is not commercially deployable.

On the other hand, although diversity could increase the probability of discovering a fatal flaw, standardization is likely to increase safety through (1) maximizing learning-by-doing in Stage 1 and learning-by-using in Stage 2 and (2) minimizing the effort of the safety regulator to monitor safety. See, for example, Duffey and Scull (2003, p. 105) comparing safety in the UK chemical industry and the US nuclear power industry.

Assume that the probability of an underlying flaw, π, is equal for all technologies: $\pi_j = \pi$. Assume that the consequence is that all plants of the flawed type are closed at the beginning of Stage 2 (i.e., the flaw is discovered when the plant begins operation). Therefore, the expected loss, L, is $(\pi + \pi^2 + \ldots + \pi^M) \cdot (NPV_1 / M)$, from Equation (6). For example, with only one demonstrated technology, $L = \pi \cdot NPV_1$, i.e., the entire NPV of the demonstration plants is at risk. With two technologies, the expected loss from one failing technology is $\pi\,(NPV_2 / 2)$, plus the possibility that both technologies fail: $\pi^2\,(NPV_1 / 2)$. With six different technologies, the expected loss is $\pi\,(NPV_1 / 6) + \pi^2\,(NPV_1 / 6) + \pi^3\,(NPV_1 / 6) + \ldots + \pi^6\,(NPV_1 / 6)$. To simplify this expression for L, note that $(\pi + \pi^2 + \ldots + \pi^M) \approx \pi$, given that $\pi^2 << 1$.[6] So, $L = \pi\,(NPV_1 / M)$ and Equation (6) becomes

$$NPV_2 \;\; = [1 - (\,\pi / M\,)]\,N\,W\,\{\delta_1\;\delta_2\,h\,[\,P\cdot CF \;-\; c - \sigma\;\log d\;\;]\;-\;k\,d^{\gamma}\}. \qquad (7)$$

IV.4. Deployment -- Construction and Operation

After learning-by-doing in the construction and learning-by-using in operation, commercial deployment of the best technology can begin. Deployment could start at any time after Stage 1. For example, deployment could start 4 years into Stage 2. Define the start of deployment to be τ_4 years since the start of Stage 1 (for example, 8 years after the start of prototype construction). In the commercialization phase, assume the following :

(1) There is at least one technology from which to choose. (If *only one* technology was demonstrated and it failed, the demonstration phase would be redone with another technology. This would delay the start of commercialization.)

(2) ($X \cdot N$) standardized units are built at a rate of N units per set with X sets in the deployment phase every τ years (e.g., 6 units every four years for 16 years: $N = 6$ and $X = 4$ for 24 commercial plants).

(3) Construction costs for all units in each set are equal to "Nth-of-a-kind" (NAOK) costs, i.e., costs after construction of N units (e.g., after constructing 6,000 MW).

(4) Opportunities to observe different nuclear energy system technologies in the demonstration phase make it possible to select the best design.

(5) Potential cost savings in the deployment phase depend on the number of technologies operated in Stage 2. The greater the number of technologies, the greater the probability of selecting the least cost technology.

Corresponding to assumptions (2) and (3), NOAK construction costs per MW for N units of a single type built in each set would be :

$$k_x(N \mid m) = k N^{-\gamma}, \tag{8}$$

where $x = 1, \ldots, X$. For example, if $N = 6$ in Stage 1 and $\gamma = 0.05$, k_x = \$1,143/kW. (For values of N less than 6, learning-by-doing in deployment reduces costs from Stage 2 to NOAK costs during the first set. This increases capital costs slightly for cases where $M > 1$ in Stage 1.)

Corresponding to assumptions (4) and (5), the selection of the type of plant with the largest expected cost savings (per MWh) could be represented as a draw from the extreme value distribution. The expected mean cost savings is :

$$\mathrm{E}(cs_3^{\max} \mid M) = \sigma(M^{\alpha} - 1), \quad 0 < \alpha < 1, \tag{9}$$

where α is a measure of learning-from-diversity in operating many types of prototypes. Diversity during demonstration phase permits more learning, reducing operating costs during the deployment phase. (However, if $M = 1$ in Stage 1, then $M^{\alpha} = 1$, and there is no learning-from-diversity.) In the deployment phase, cost savings accumulate from demonstration, so the annual cost per MWh is :

$$C_3 = c + \sigma \log d - \sigma(M^{\alpha} - 1). \tag{10}$$

For example, assume c = \$18/MWh, σ = \$1/MWh, and α = 0.25. With complete standardization in demonstration, levelized C_3 would be \$16.21/MWh and with complete diversity, C_3 = \$17.43/MWh.

The lifetime costs are discounted to the beginning of the deployment phase by δ_2, under the same assumptions as above. Also, $\delta_4 = (1 + r)^{-\tau 4}$, discounts costs to the beginning of Stage 1. (Note: to simplify the notation, overnight construction costs at the beginning of each set are escalated to the start of operation of the set, hence the $(1 + r)^{\tau} k N^{-\gamma}$ term in Equation 11a.) The expected net present value *at the beginning of deployment*, NPV_3, for the $X \cdot N$ plants is :

$$NPV_3 = \delta_4 \Sigma e^{-r x \tau} N W \{\delta_2 h [P \cdot CF - c - \sigma \log d + \sigma (M^{\alpha} - 1)] - (1+r)^{\tau} k N^{-\gamma}\} \qquad (11a)$$

summed over $x = 1, \ldots X$. This must be modified if flaws are discovered at the beginning of Stage 2 in *all* of the technologies (i.e., with probability π^M) and the program is delayed another τ years:

$$NPV_4 = [\delta_4 \Sigma e^{-r x \tau} - \pi^M (1 + r)^{-\tau} \delta_4 \Sigma e^{-r x \tau}] \cdot$$
$$N W \{\delta_2 h [P \cdot CF - c - \sigma \log d + \sigma (M^{\alpha} - 1)] - (1+r)^{\tau} k N^{-\gamma}\} \qquad (11b)$$

The net present value of deployment depends on the learning-by-doing parameter γ, the learning-from-diversity parameter α, and the probability of a fatal flaw, π. The next section explores optimal prototype diversity as a function of γ, α, and π.

IV.5. Optimal Diversity

What is the NPV maximizing value of M, the number of different plant types to build in Stage 1? Expressing all costs at the beginning of the program (see Equations 7 and 11b) [7],

$$NPV(N|M) = [1 - (\pi / M)] N W \{\delta_1 \delta_2 h [P \cdot CF - c - \sigma \log d] - k d^{\gamma}\}$$
$$+ [\delta_4 \Sigma e^{-r x \tau} - \pi^M (1 + r)^{-\tau} \delta_4 \Sigma e^{-r x \tau}] \cdot$$
$$N W \{\delta_2 h [P \cdot CF - c - \sigma \log d + \sigma (M^{\alpha} - 1)] - (1+r)^{\tau} k N^{-\gamma}\} \quad (12)$$

Given the analytic complexity of evaluating the relationship $\partial NPV / \partial M$, this is analyzed numerically. In Tables 3A through 3D present the optimal number of technology types for values of (1) π = 0.0 to 0.9, (2) α = 0.0 to 0.9, and (3) γ = 0.01, 0.05, 0.10, and 0.15.

Considering Tables 3A through 3D, only for unreasonably high values of α and π is diversity better (i.e., has a higher NPV) than complete standardization. For example, for learning-from-diversity rates (α) of 0.6 and below and probabilities of failure (π) of 50% and below, standardization dominates all other options. Therefore, the optimality of some diversity depends on *unrealistically high* values for α and π at reasonable values for learning-by-doing during prototype construction (γ). Learning-by-using in construction and learning-by-doing in operation dominate learning-from-diversity and learning-about-flaws.

IV.6. Policy Conclusions and Further Research

Given the importance of economies of multiple unit construction in determining the optimal number of technologies to demonstrate, understanding construction economies for particular technologies will be a critical task during the performance phase of the Generation IV initiative. Given the decline in virtual engineering costs and the high cost of demonstrating new technologies, engineering must consider the entire deployment scenario and how costs decline with the number of units constructed. The project manager should require explicit specification of learning-by-doing in prototype construction from technology design teams. For appropriate functional forms and parameters for learning curves, see Duffey and Saull (2003).

Of course, this is a simple model. Future research should address the following issues. First, the assumption of equally sized technologies must be relaxed, given the importance of learning-by-doing in construction. Building a large number of small (modular) units could yield significant savings. See Rothwell (2001). Second, given the importance of safety for the public and commercial acceptance of new nuclear energy technologies, the possibility of a catastrophic accident should be explicitly modeled. Third, the model of learning-by-using in operations relies on extreme value statistics and the model of a fatal flaw relies on point probabilities. The model should be embedded in a probabilistic framework where (1) probability distributions could be specified for key variables and parameters and (2) Monte Carlo simulations could be done to determine the robustness of the conclusion regarding standardization in the demonstration phase. This research should yield a model that can be generalized to other new technology development efforts, such as those in the chemical industry.

ENDNOTES:

1. This paper is based on Rothwell (2003b), which is based on David and Rothwell (1996). For more information on nuclear power economics, see Rothwell (2003a).

2. Currently, the GIF program assumes that research and development costs are not included in the cost of production. However, prototype costs are full amortized over the life of the nuclear energy system.

3. Rothwell (2001) presents a similar model where power plants vary in size from 50 MW to 1000MW. The model shows that learning-by-doing in series construction and scale economies from increases in size favor technologies with the smallest and largest plants, respectively. Here, because all plants are the same size, scale economies are not represented.

4. Advanced Boiling Water Reactors (ABWR, net 1,315 MW) have been built in Japan in 48 months. Generation IV design teams are attempting to reduce construction times to below those of currently available nuclear power plants, such as the ABWR.

5. This analysis assumes that all operation costs are fixed during a year. This is true for most operation and maintenance costs at nuclear power plants. See Rothwell (2000).

6. In the analytic exposition the approximation $(\pi + \pi^2 + . . . + \pi^M) \approx \pi$ is used. However, in the numeric calculations in Table 2 the probability is not approximated.

7. Earlier versions of the paper assumed learning with successive sets of deployment. To isolate the influence of standardization in the demonstration phase, the assumption of constant Nth-of-a-kind costs was made.

Table 1: Parameter Values

Parameter	Definition	Units	
P	Price of Electricity	$/MWh	35
N	Number of units per stage		6
k	Prototype Overnight cost/kW	$/kW	$1,250
gamma	Learning in construction	%	5%
W	Capacity of units in MW	MW	1000
c	Operating cost	$/MWh	$18
sigma	Standard deviation in CS	$/MWh	$1
x	Stages in Deployment		4
r	Discount rate	%	7%
CF	Capacity Factor	%	90%
tau	Construction time	years	4
tau2	Nuclear Power Plant Lifetime	years	40
tau4	Years to Deployment	years	12
delta1	Discount factor t=4	%	76%
delta2	Present value of annuity		13.33
delta4	Discount factor t=12	%	43%
alpha	Learning during Deployment	%	25%
pi	Probability of a Fatal Flaw	%	10%

Table 2		**Units**	**Eq**				
M	Number of technologies			**1**	**2**	**3**	**6**
n	Number of units in a set			6	3	2	1
d	Diversity in Demonstration			0.167	0.333	0.500	1.000
k(n)	Construction cost per MW	$/kW	1	$1,143	$1,183	$1,207	$1,250
K	Total capital cost	$B	3	$6.86	$7.10	$7.24	$7.50
K/MWh	Capital Cost/MWh	$/MWh		$10.87	$11.26	$11.49	$11.89
C2	Realized operating cost	$/MWh	5	$16.21	$16.90	$17.31	$18.00
$/MWh	Average Demonstration cost	$/MWh		$27.08	$28.16	$28.79	$29.89
NPV2	**Net Present Value of Demo**	$B	7	**$1.24**	**$0.63**	**$0.27**	**-$0.35**
k3	Average K cost in Deployment	$/kW	8	$1,143	$1,148	$1,154	$1,165
k3/MWh	Average Capital Cost/MWh	$/MWh		$10.87	$10.92	$10.98	$11.09
C3	Average Operating Cost	$/MWh	10	$16.21	$16.71	$16.99	$17.43
$/MWh	Average Cost in Deployment	$/MWh		$27.08	$27.63	$27.97	$28.52
NPV	**Total Net Present Value**	$B	12	**$3.08**	**$2.19**	**$1.58**	**$0.49**

Table 3A: Optimal Number of Technologies for $\gamma = 0.01$ (columns = α, rows = π)

0.01	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	1	1	1	1	1	1	1	1	6	6
0.1	1	1	1	1	1	1	1	1	6	6
0.2	1	1	1	1	1	1	1	1	6	6
0.3	1	1	1	1	1	1	1	1	6	6
0.4	1	1	1	1	1	1	1	6	6	6
0.5	1	1	1	1	1	1	1	6	6	6
0.6	1	1	1	1	1	1	1	6	6	6
0.7	1	1	1	1	1	1	6	6	6	6
0.8	1	1	1	1	1	1	6	6	6	6
0.9	1	1	1	1	1	1	6	6	6	6

Table 3B: Optimal Number of Technologies for $\gamma = 0.05$ (columns = α, rows = π)

0.05	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	1	1	1	1	1	1	1	1	1	6
0.1	1	1	1	1	1	1	1	1	1	6
0.2	1	1	1	1	1	1	1	1	1	6
0.3	1	1	1	1	1	1	1	1	6	6
0.4	1	1	1	1	1	1	1	1	6	6
0.5	1	1	1	1	1	1	1	6	6	6
0.6	1	1	1	1	1	1	1	6	6	6
0.7	1	1	1	1	1	1	6	6	6	6
0.8	1	1	1	1	1	1	6	6	6	6
0.9	1	1	1	1	1	1	6	6	6	6

Table 3C: Optimal Number of Technologies for $\gamma = 0.10$ (columns = α, rows = π)

0.10	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	1	1	1	1	1	1	1	1	1	1
0.1	1	1	1	1	1	1	1	1	1	1
0.2	1	1	1	1	1	1	1	1	1	6
0.3	1	1	1	1	1	1	1	1	1	6
0.4	1	1	1	1	1	1	1	1	6	6
0.5	1	1	1	1	1	1	1	2	6	6
0.6	1	1	1	1	1	1	2	6	6	6
0.7	1	1	1	1	1	1	3	6	6	6
0.8	1	1	1	1	1	1	6	6	6	6
0.9	1	1	1	1	1	1	6	6	6	6

Table 3D: Optimal Number of Technologies for $\gamma = 0.15$ (columns = α, rows = π)

0.15	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	1	1	1	1	1	1	1	1	1	1
0.1	1	1	1	1	1	1	1	1	1	1
0.2	1	1	1	1	1	1	1	1	1	1
0.3	1	1	1	1	1	1	1	1	1	1
0.4	1	1	1	1	1	1	1	1	2	6
0.5	1	1	1	1	1	1	1	2	6	6
0.6	1	1	1	1	1	2	2	3	6	6
0.7	1	1	1	1	1	2	3	6	6	6
0.8	1	1	1	1	1	2	6	6	6	6
0.9	1	1	1	1	1	1	6	6	6	6

IV.6 REFERENCES

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Appendix A

Articles posted to Usenet newsgroup archives were examined for information flows about the Therac-25 event using the Google Groups search facility. Google has fully integrated the Usenet archives dating back to 1981 into Google Groups and offers access to more than 700 million articles. The specific newsgroups searched are: comp.risks, comp.software-eng, sci.med and all of the newsgroups under sci.med (31 in total), and sci.engr and all of the newsgroups under sci.engr (also 31 in total). Of the newsgroups under sci.med and sci.engr, four seem of particular relevance: sci.med.physics, sci.med.radiology, sci.engr.biomed, and sci.eng.safety. Articles posted in any language were investigated that mentioned the following words or phrases: "Therac-25", "Therac", "AECL", "radiation", "Leveson", or "Theratron". We were not able to find information about the starting date of the newsgroups, but the earliest date that we could find an article posted on comp.risks was 12 July, 1985, for comp.software-eng it was 18 April, 1985, for sci.med it was 16 October, 1986 (for sci.med.physics and sci.med.radiology it was 1 September, 1989 and 28 March, 1994, respectively), and for sci.engr it was 4 October, 1990 (for sci.engr.biomed and sci.eng.safety it was 8 February, 1992 and 28 March, 1995, respectively).

We could not find information about the number of individual articles posted in each newsgroup, but there is information about the number of "threads" in each newsgroup (these are more or less continuous chains of articles on single topics sharing common reference headers). Note that each thread consists of a minimum of one article and in some cases can consist of up to several hundred articles. Note also that the same article can be "cross-posted" to several newsgroups. No adjustment or allowance has been made for this feature on the basis that cross-postings still represent new sources of information to each of the different groups included. By 7 May, 2003, comp.software-eng had approximately 72,800 threads posted on it, sci.med. had approximately 199,000 threads posted on it and approximately 1.12 million threads for all twenty-three newsgroups under it (for sci.med.physics and sci.med.radiology it was 9,300 and 19,300 threads respectively), and sci.eng had 34,700 threads posted on it and 449,438 threads for all twenty-four newsgroups under it (for sci.engr.biomed and sci.engr.safety it was 12,400 and 13,000 threads respectively). Comp.risks is a moderated newsgroup (articles are sent to the moderator who edits and filters them, sometimes including comments of his own, and then posts the results) and instead of threads being posted on it, digests, or collections of edited and filtered articles, are periodically posted on it. By May, 2003, 1,910 digests had been posted on this newsgroup.

To give a crude idea about the numbers of articles per thread consider the months of January and February in 2003. During January, 87 threads were started in comp.software-eng comprising 478 articles and during February 88 threads were started comprising 1,459 articles. This gives an average of 11.1 articles per thread. During January, nine digests were posted to comp.risks comprising 115 articles in total and during February six digests were posted comprising 87 articles in total. This gives an average of 12.8 articles per digest. During January, 35 threads were started in sci.med.radiology comprising 109 articles and during February 17 articles were started comprising 23 articles. This gives an average of 2.5 articles per thread. For sci.engr.biomed the figures are 13 threads and 29 articles for January, 14 threads and 23 articles for February, and an average of 1.9 articles per thread.

The articles were classified using four dimensions: the month and year they were posted, the geographic location of the poster, the type of article posted, and the organisational affiliation of the poster. The geographic locations considered are North America (defined as the United

States and Canada), Other English Speaking Countries (defined as Australia, New Zealand, the United Kingdom, and Ireland), Europe (excluding the United Kingdom and Ireland, and also not including Turkey and Russia), and All Other Countries. The affiliation of the poster is classified as Academic (universities and research institutes), Government, Commercial, and Other. The country of origin of the poster and their affiliation are derived from the email address used or failing this, the signature of the sender. Sometimes this information involved a further search of the internet to confirm or clarify matters. If the affiliation is not identifiable from this process then it is included in the Other category. Only one article, from a sci.med newsgroup, could not be classified using this system. Finally, articles are also defined as Personal (including personal correspondence and discussions between Usenet respondents) and Announcements (including announcements about conferences, course offerings, FAQs, and summaries of discussions, which are similar in nature to FAQs).

A detailed listing of the newsgroups examined is as follows:

comp.risks

comp.software-eng

sci.engr
sci.engr.advanced-tv
sci.engr.heat-vent-ac
sci.engr.analysis
sci.engr.biomed
sci.engr.chem
sci.engr.civil
sci.engr.coastal
sci.engr.color
sci.engr.control
sci.engr.electrical
sci.engr.electrical.compliance
sci.engr.electrical.sys-protection
sci.engr.geomechanics
sci.engr.joining
sci.engr.joining.misc
sci.engr.joining.welding
sci.engr.lighting
sci.engr.manufacturing
sci.engr.marine
sci.engr.marine.hydrodynamics
sci.engr.mech
sci.engr.metallurgy
sci.engr.micromachining
sci.engr.mining
sci.engr.radar+sonar
sci.engr.safety
sci.engr.semiconductors
sci.engr.surveying
sci.engr.television
sci.engr.television.advanced
sci.engr.television.broadcast

sci.med
sci.med.aids
sci.med.cannabis
sci.med.cardiology
sci.med.dentistry
sci.med.diseases
sci.med.diseases.als
sci.med.diseases.alzheimer
sci.med.diseases.cancer
sci.med.diseases.hepatitis
sci.med.diseases.lyme
sci.med.diseases.mult-sclerosis
sci.med.diseases.osteoporosis
sci.med.immunology
sci.med.midwifery
sci.med.nursing
sci.med.nutrition
sci.med.obgyn
sci.med.occupational
sci.med.orthopedics
sci.med.pathology
sci.med.pharmacy
sci.med.physics
sci.med.prostate
sci.med.prostate.bph
sci.med.prostate.cancer
sci.med.prostate.prostatitis
sci.med.psychobiology

sci.med.informatics
sci.med.laboratory
sci.med.radiology
sci.med.radiology.interventional

Table A1: Details of Articles from North American Posters to comp.risks

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of Total
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	1	0	0	0	1	1	0	0	3	7.3
1987	4	0	4	1	0	0	0	0	9	22.0
1988	1	0	0	0	0	0	0	0	1	2.4
1989	4	1	1	1	2	0	0	0	9	22.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	2	1	1	0	1	2	0	0	7	17.1
1992	2	0	0	1	1	0	0	0	4	9.8
1993	3	0	0	0	0	0	0	0	3	7.3
1994	0	0	0	0	0	0	0	0	0	0.0
1995	2	0	0	0	1	0	0	0	3	7.3
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	1	0	0	0	0	0	0	0	1	2.4
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	1	0	0	0	1	2.4
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	20	2	6	3	7	3	0	0	41	100.0
% of All	48.8	4.9	14.6	7.3	17.1	7.3	0.0	0.0	100.0	

Table A2: Details of Articles from Other English Speaking Posters to comp.risks

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of Total
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	1	0	0	0	0	0	0	0	1	25.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	2	0	0	0	0	0	0	0	2	50.0
1993	1	0	0	0	0	0	0	0	1	25.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	4	0	0	0	0	0	0	0	4	100.0
% of All	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table A3: Details of Articles from European Posters to comp.risks

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of Total
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	1	0	0	0	0	0	0	0	1	2.4
1989	1	0	0	0	0	0	0	0	1	2.4
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	2	0	0	0	0	0	0	0	2	4.9
% of All	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	

Table A4: Details of Articles from All Other Countries' Posters to comp.risks

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of Total
1985	0	0	0	0	0	0	0	0	0	na
1986	0	0	0	0	0	0	0	0	0	na
1987	0	0	0	0	0	0	0	0	0	na
1988	0	0	0	0	0	0	0	0	0	na
1989	0	0	0	0	0	0	0	0	0	na
1990	0	0	0	0	0	0	0	0	0	na
1991	0	0	0	0	0	0	0	0	0	na
1992	0	0	0	0	0	0	0	0	0	na
1993	0	0	0	0	0	0	0	0	0	na
1994	0	0	0	0	0	0	0	0	0	na
1995	0	0	0	0	0	0	0	0	0	na
1996	0	0	0	0	0	0	0	0	0	na
1997	0	0	0	0	0	0	0	0	0	na
1998	0	0	0	0	0	0	0	0	0	na
1999	0	0	0	0	0	0	0	0	0	na
2000	0	0	0	0	0	0	0	0	0	na
2001	0	0	0	0	0	0	0	0	0	na
2002	0	0	0	0	0	0	0	0	0	na
2003	0	0	0	0	0	0	0	0	0	na
Total	0	0	0	0	0	0	0	0	0	na
% of All	na	na	na	na	na	na	na	na	na	

Table A5: Geographic Area of Posters by Year for comp.risks

	NA	OE	EU	AO	Total	% of All
1985	0	0	0	0	0	0.0
1986	3	0	0	0	3	6.4
1987	9	0	0	0	9	19.1
1988	1	0	1	0	2	4.3
1989	9	0	1	0	10	21.3
1990	0	1	0	0	1	2.1
1991	7	0	0	0	7	14.9
1992	4	2	0	0	6	12.8
1993	3	1	0	0	4	8.5
1994	0	0	0	0	0	0.0
1995	3	0	0	0	3	6.4
1996	0	0	0	0	0	0.0
1997	0	0	0	0	0	0.0
1998	0	0	0	0	0	0.0
1999	1	0	0	0	1	2.1
2000	0	0	0	0	0	0.0
2001	1	0	0	0	1	2.1
2002	0	0	0	0	0	0.0
2003	0	0	0	0	0	0.0
Total	41	4	2	0	47	100.0
% of All	87.2	8.5	4.3	0.0	100.0	

Table A6: Affiliation of Article Posters by Year for comp.risks

	Acad.	Govt	Comm	Other
1985	0	0	0	0
1986	1	0	2	0
1987	4	5	0	0
1988	2	0	0	0
1989	6	2	2	0
1990	1	0	0	0
1991	3	1	3	0
1992	4	1	1	0
1993	4	0	0	0
1994	0	0	0	0
1995	2	0	1	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	1	0	0	0
2000	0	0	0	0
2001	0	0	1	0
2002	0	0	0	0
2003	0	0	0	0
Total	28	9	10	0
% of All	59.6	19.1	21.3	0.0

Table A7: Type of Article by Year for comp.risks

	Personal	Announce
1985	0	0
1986	2	1
1987	8	1
1988	2	0
1989	8	2
1990	1	0
1991	4	3
1992	5	1
1993	4	0
1994	0	0
1995	3	0
1996	0	0
1997	0	0
1998	0	0
1999	1	0
2000	0	0
2001	1	0
2002	0	0
2003	0	0
Total	39	8
% of All	83.0	17.0

Table A8: Number of Different Article Posters by Geographic Area for comp.risks

	No.	% of All Articles
NA	25	61.0
OE	3	75.0
EU	1	50.0
AO	na	na
World	29	61.7

Table A9: Details of Articles from North American Posters to comp.software-eng

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of All
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	1	0	0	0	0	0	0	1	1.0
1988	0	0	0	0	1	0	0	0	1	1.0
1989	2	1	0	0	1	1	0	0	5	5.0
1990	1	0	0	0	0	0	0	0	1	1.0
1991	1	3	0	0	0	0	0	0	4	4.0
1992	0	0	0	0	0	0	1	0	1	1.0
1993	5	1	0	0	13	0	3	0	22	21.8
1994	3	0	0	0	20	6	0	0	29	28.7
1995	0	2	0	1	4	3	0	0	10	9.9
1996	0	0	0	0	2	2	0	0	4	4.0
1997	4	0	0	0	2	0	0	0	6	5.9
1998	3	0	2	0	5	0	1	0	11	10.9
1999	2	0	0	0	0	0	2	0	4	4.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	1	0	0	0	1	1.0
2003	0	0	0	0	1	0	0	0	1	1.0
Total	21	8	2	1	50	12	7	0	101	100.0
% of All	20.8	7.9	2.0	1.0	49.5	11.9	6.9	0.0	100.0	

Table A10: Details of Articles from Other English Speaking Posters to comp.software-eng

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of All
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	1	0	0	0	0	0	0	0	1	33.3
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	1	0	1	33.3
1999	0	0	0	0	1	0	0	0	1	33.3
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	1	0	0	0	1	0	1	0	3	100.0
% of All	33.3	0.0	0.0	0.0	33.3	0.0	33.3	0.0	100.0	

Table A11: Details of Articles from European Posters to comp.software-eng

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	1	0	0	0	1	1.0
1996	0	0	0	0	1	0	0	0	1	1.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	0	0	0	0	2	0	0	0	2	2.0
% of All	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	2.0	

Table A12: Details of Articles from Other Countries' Posters to comp.software-eng

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	na
1986	0	0	0	0	0	0	0	0	0	na
1987	0	0	0	0	0	0	0	0	0	na
1988	0	0	0	0	0	0	0	0	0	na
1989	0	0	0	0	0	0	0	0	0	na
1990	0	0	0	0	0	0	0	0	0	na
1991	0	0	0	0	0	0	0	0	0	na
1992	0	0	0	0	0	0	0	0	0	na
1993	0	0	0	0	0	0	0	0	0	na
1994	0	0	0	0	0	0	0	0	0	na
1995	0	0	0	0	0	0	0	0	0	na
1996	0	0	0	0	0	0	0	0	0	na
1997	0	0	0	0	0	0	0	0	0	na
1998	0	0	0	0	0	0	0	0	0	na
1999	0	0	0	0	0	0	0	0	0	na
2000	0	0	0	0	0	0	0	0	0	na
2001	0	0	0	0	0	0	0	0	0	na
2002	0	0	0	0	0	0	0	0	0	na
2003	0	0	0	0	0	0	0	0	0	na
Total	0	0	0	0	0	0	0	0	0	na
% of All	na	na	na	na	na	na	na	na	na	

Table A13: Geographic Area of Posters by Year for comp.software-eng

	NA	OE	EU	AO	Total	% of All
1985	0	0	0	0	0	0.0
1986	0	0	0	0	0	0.0
1987	1	0	0	0	1	0.9
1988	1	0	0	0	1	0.9
1989	5	0	0	0	5	4.7
1990	1	0	0	0	1	0.9
1991	4	0	0	0	4	3.8
1992	1	0	0	0	1	0.9
1993	22	0	0	0	22	20.8
1994	29	1	0	0	30	28.3
1995	10	0	1	0	11	10.4
1996	4	0	1	0	5	4.7
1997	6	0	0	0	6	5.7
1998	11	1	0	0	12	11.3
1999	4	1	0	0	5	4.7
2000	0	0	0	0	0	0.0
2001	0	0	0	0	0	0.0
2002	1	0	0	0	1	0.9
2003	1	0	0	0	1	0.9
Total	101	3	2	0	106	100.0
% of All	95.3	2.8	1.9	0.0	100.0	

Table A14: Affiliation of Article Posters by Year for comp.software-eng

	Acad.	Govt	Comm	Other
1985	0	0	0	0
1986	0	0	0	0
1987	1	0	0	0
1988	0	0	1	0
1989	3	0	2	0
1990	1	0	0	0
1991	4	0	0	0
1992	0	0	0	1
1993	6	0	13	3
1994	4	0	26	0
1995	2	1	8	0
1996	0	0	5	0
1997	4	0	2	0
1998	3	2	5	2
1999	2	0	1	2
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	1	0
2003	0	0	1	0
Total	30	3	65	8
% of All	28.3	2.8	61.3	7.5

Table A15: Type of Article by Year for comp.software-eng

	Personal	Announce
1985	0	0
1986	0	0
1987	0	1
1988	1	0
1989	3	2
1990	1	0
1991	1	3
1992	1	0
1993	21	1
1994	24	6
1995	5	6
1996	3	2
1997	6	0
1998	12	0
1999	5	0
2000	0	0
2001	0	0
2002	1	0
2003	1	0
Total	85	21
% of All	80.2	19.8

Table A16: Number of Different Article Posters by Geographic Area for comp.software-eng

	No.	% of All Articles
NA	54	53.5
OE	3	100.0
EU	2	100.0
AO	na	na
World	59	55.7

Table A17: Details of Articles from North American Posters to sci.engr.*

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of All
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	3	3	0	0	6	20.0
1995	0	0	0	6	2	4	0	0	12	40.0
1996	0	0	0	0	5	4	0	0	9	30.0
1997	0	0	0	0	2	0	0	0	2	6.7
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	1	0	0	0	0	0	0	1	3.3
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	0	1	0	6	12	11	0	0	30	100.0
% of All	0.0	3.3	0.0	20.0	40.0	36.7	0.0	0.0	100.0	

Table A18: Details of Articles from Other English Speaking Posters to sci.engr.*

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of All
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	1	0	0	0	2	0	0	0	3	100.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	1	0	0	0	2	0	0	0	3	100.0
% of All	33.3	0.0	0.0	0.0	66.7	0.0	0.0	0.0	100.0	

Table A19: Details of Articles from European Posters to sci.engr.*

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of All
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	1	0	0	0	1	3.3
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	0	0	0	0	1	0	0	0	1	3.3
% of All	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	3.3	

Table A20: Details of Articles from All Other Countries' Posters to sci.engr.*

	Academic		Government		Commercial		Other/Non-Ident.			
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce	Total	% of All
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	1	0	0	0	1	100.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	0	0	0	0	1	0	0	0	1	100.0
% of All	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0	

Table A21: Geographic Area of Posters by Year for sci.engr.*

	NA	OE	EU	AO	Total	% of All
1985	0	0	0	0	0	0.0
1986	0	0	0	0	0	0.0
1987	0	0	0	0	0	0.0
1988	0	0	0	0	0	0.0
1989	0	0	0	0	0	0.0
1990	0	0	0	0	0	0.0
1991	0	0	0	0	0	0.0
1992	0	0	0	0	0	0.0
1993	0	0	0	0	0	0.0
1994	6	0	0	0	6	17.1
1995	12	0	0	0	12	34.3
1996	9	0	0	0	9	25.7
1997	2	3	0	0	5	14.3
1998	0	0	0	0	0	0.0
1999	0	0	0	1	1	2.9
2000	1	0	1	0	2	5.7
2001	0	0	0	0	0	0.0
2002	0	0	0	0	0	0.0
2003	0	0	0	0	0	0.0
Total	30	3	1	1	35	100.0
% of All	85.7	8.6	2.9	2.9	100.0	

Table A22: Affiliation of Article Posters by Year for sci.engr.*

	Acad.	Govt	Comm	Other
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	0	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	6	0
1995	0	6	6	0
1996	0	0	9	0
1997	1	0	4	0
1998	0	0	0	0
1999	0	0	1	0
2000	1	0	1	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
Total	2	6	27	0
% of All	5.7	17.1	77.1	0.0

Table A23: Type of Article by Year for sci.engr.*

	Personal	Announce
1985	0	0
1986	0	0
1987	0	0
1988	0	0
1989	0	0
1990	0	0
1991	0	0
1992	0	0
1993	0	0
1994	3	3
1995	2	10
1996	5	4
1997	5	0
1998	0	0
1999	1	0
2000	1	1
2001	0	0
2002	0	0
2003	0	0
Total	17	18
% of All	48.6	51.4

Table A24: Number of Different Article Posters by Geographic Area for sci.engr.*

	No.	% of All Articles
NA	10	33.3
OE	3	100.0
EU	1	100.0
AO	1	100.0
World	15	42.9

Table A25: Details of Articles from North American Posters to sci.med.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	1	0	0	0	0	0	0	0	1	5.9
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	1	0	0	0	0	0	0	0	1	5.9
1993	1	0	0	0	0	0	0	0	1	5.9
1994	4	0	0	0	3	4	0	0	11	64.7
1995	1	0	0	0	0	0	0	0	1	5.9
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	1	0	0	0	1	5.9
1998	1	0	0	0	0	0	0	0	1	5.9
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	9	0	0	0	4	4	0	0	17	100.0
% of All	52.9	0.0	0.0	0.0	23.5	23.5	0.0	0.0	100.0	

Table A26: Details of Articles from Other English Speaking Posters to sci.med.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	2	0	0	0	0	0	0	0	2	100.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	0	0	0	0	0	0	0	0	0	0.0
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	2	0	0	0	0	0	0	0	2	100.0
% of All	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table A27: Details of Articles from European Posters to sci.med.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	0.0
1986	0	0	0	0	0	0	0	0	0	0.0
1987	0	0	0	0	0	0	0	0	0	0.0
1988	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	0	0	0	0	0	0	0	0.0
1994	0	0	0	0	0	0	0	0	0	0.0
1995	0	0	0	0	0	0	0	0	0	0.0
1996	0	0	0	0	0	0	0	0	0	0.0
1997	0	0	0	0	0	0	0	0	0	0.0
1998	1	0	0	0	0	0	0	0	1	5.9
1999	0	0	0	0	0	0	0	0	0	0.0
2000	0	0	0	0	0	0	0	0	0	0.0
2001	0	0	0	0	0	0	0	0	0	0.0
2002	0	0	0	0	0	0	0	0	0	0.0
2003	0	0	0	0	0	0	0	0	0	0.0
Total	1	0	0	0	0	0	0	0	1	5.9
% of All	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	

Table A28: Details of Articles from All Other Countries' Posters to sci.med.*

	Academic		Government		Commercial		Other/Non-Ident.		Total	% of All
	Personal	Announce	Personal	Announce	Personal	Announce	Personal	Announce		
1985	0	0	0	0	0	0	0	0	0	na
1986	0	0	0	0	0	0	0	0	0	na
1987	0	0	0	0	0	0	0	0	0	na
1988	0	0	0	0	0	0	0	0	0	na
1989	0	0	0	0	0	0	0	0	0	na
1990	0	0	0	0	0	0	0	0	0	na
1991	0	0	0	0	0	0	0	0	0	na
1992	0	0	0	0	0	0	0	0	0	na
1993	0	0	0	0	0	0	0	0	0	na
1994	0	0	0	0	0	0	0	0	0	na
1995	0	0	0	0	0	0	0	0	0	na
1996	0	0	0	0	0	0	0	0	0	na
1997	0	0	0	0	0	0	0	0	0	na
1998	0	0	0	0	0	0	0	0	0	na
1999	0	0	0	0	0	0	0	0	0	na
2000	0	0	0	0	0	0	0	0	0	na
2001	0	0	0	0	0	0	0	0	0	na
2002	0	0	0	0	0	0	0	0	0	na
2003	0	0	0	0	0	0	0	0	0	na
Total	0	0	0	0	0	0	0	0	0	na
% of All	na	na	na	na	na	na	na	na	na	

Table A29: Geographic Area of Posters by Year for sci.med.*

	NA	OE	EU	AO	Total	% of All
1985	0	0	0	0	0	0.0
1986	0	0	0	0	0	0.0
1987	0	0	0	0	0	0.0
1988	0	0	0	0	0	0.0
1989	1	0	0	0	1	5.0
1990	0	0	0	0	0	0.0
1991	0	0	0	0	0	0.0
1992	1	0	0	0	1	5.0
1993	1	0	0	0	1	5.0
1994	11	2	0	0	13	65.0
1995	1	0	0	0	1	5.0
1996	0	0	0	0	0	0.0
1997	1	0	0	0	1	5.0
1998	1	0	1	0	2	10.0
1999	0	0	0	0	0	0.0
2000	0	0	0	0	0	0.0
2001	0	0	0	0	0	0.0
2002	0	0	0	0	0	0.0
2003	0	0	0	0	0	0.0
Total	17	2	1	0	20	100.0
% of All	85.0	10.0	5.0	0.0	100.0	

Table A30: Affiliation of Article Posters by Year for sci.med.*

	Acad.	Govt	Comm	Other
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	1	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	1	0	0	0
1993	1	0	0	0
1994	6	0	7	0
1995	1	0	0	0
1996	0	0	0	0
1997	0	0	1	0
1998	2	0	0	0
1999	0	0	0	0
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
Total	12	0	8	0
% of All	60.0	0.0	40.0	0.0

Table A31: Type of Article by Year for sci.med.*

	Personal	Announce
1985	0	0
1986	0	0
1987	0	0
1988	0	0
1989	1	0
1990	0	0
1991	0	0
1992	1	0
1993	1	0
1994	9	4
1995	1	0
1996	0	0
1997	1	0
1998	2	0
1999	0	0
2000	0	0
2001	0	0
2002	0	0
2003	0	0
Total	16	4
% of All	80.0	20.0

Table A32: Number of Different Article Posters by Geographic Area for sci.med.*

	No.	% of All Articles
NA	11	64.7
OE	1	50.0
EU	1	100.0
AO	na	na
World	13	65.0

Appendix B

Journal citations of Nancy Leveson's 1995 book, *Safeware: System Safety and Computers*, were examined for information about how knowledge of the Therac-25 case diffused across countries, organisations, subjects, and over time. The details of the citing articles were collected from the Web of Science using the full search feature; this includes the expanded Science Citation Index, the Social Science Citation Index, and the Arts and Humanities Citation Index (all three indices range from 1995 until the present). All languages and all documents were allowed with searches specifyin Leveson as the cited author in conjunction with combinations of the significant words in the title as the cited work. Overall, 119 articles from the publication of the book in 1995 until May 2003 cited the book (see table B18). It is worth highlighting that the citations are only those of journal articles, excluding books and chapters in books, conference proceedings published as books or CD-ROMs, and the like.

The articles were classified using four dimensions: the year the citing article was published, the geographic location(s) of the authors of the citing article, the organisational affiliation(s) of the authors of the citing articles, and the main subject of the citing articles. The geographic locations considered are North America (defined as the United States and Canada), Other English Speaking Countries (defined as Australia, New Zealand, the United Kingdom, and Ireland), Europe (excluding the United Kingdom and Ireland, and also not including Turkey and Russia), and All Other Countries. The affiliation(s) of the authors is classified as Academic (universities and research institutes), Government, Commercial, and Other. The country(ies) of origin of the authors and their affiliation(s) are derived from the address(es) used. Sometimes this information involved a further search to confirm or clarify matters. If the affiliation is not identifiable from this process then it is included in the Other category. The details of all citing articles could be identified using this process. Authors who had multiple affiliations were classified as a single type if the affiliations were of the same type, or were treated as multiple authors if their affiliations were of different types. Equally, authors who were located in more than one geographic location were classified as a single types if the geographic locations were of the same type, or were treated as multiple authors if the geographic locations were of different types. The categories of subjects of the articles were computing, engineering (other than computer science or software engineering), medical, and other. Other is what is left over, typically management, ethics, and the like. In many cases the citing articles covered more than one area, but the main focus of the article was used to classify it along with information about the affiliation of the authors and the professional society (if one was involved) affiliated with the relevant journal in which the citing article was published. In determing how many distinct affiliations were associated with the citing articles, two approaches were used: defining affiliation by the name of the relevant organisation sub-unit (such as the university or company department) and defining affiliation by the name of the relevant organisation (such as the university or the company).

Three different methods are used to record information about the citing articles in an attempt to allow for multiple authors and multiple affiliation, since the aim of the exercise is to learn about diffusion of knowledge of the Therac-25 failure and any related learning. The first method focuses on the authors of each citing article (tables B1 to B8), the second method focuses on the affiliations of the authors of each citing article (tables B9 to B17), and the third method focuses on the subject of each citing article (tables B18 to B35. Note that this also means that the focus is on each citing article rather than worrying about multiple authors, affiliations, or both).

Table B1: Journal Citations of Leveson (1995) by Numbers of Citing North American Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth		
1995									1								1	1.4
1996	2																2	2.8
1997	1								2	1							4	5.6
1998	7								3	3				1			14	19.7
1999	6	1			1				2	1			1				12	16.9
2000	7	6			1	1			4								19	26.8
2001		1									1						2	2.8
2002	3	4			1					3	1						12	16.9
2003			3								2						5	7.0
Total	26	12	3	0	3	1	0	0	12	8	4	0	1	1	0	0	71	100.0
%Tot	36.6	16.9	4.2	0.0	4.2	1.4	0.0	0.0	16.9	11.3	5.6	0.0	1.4	1.4	0.0	0.0	100.0	

Table B2: Journal Citations of Leveson (1995) by Numbers of Citing Other English Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth		
1995																	0	0.0
1996	4																4	4.2
1997	2	3						1									6	6.3
1998	9	3	2		4												18	18.8
1999	13	8				1											22	22.9
2000	20	7		3			1										31	32.3
2001	1			3					5	1							10	10.4
2002	2	3															5	5.2
2003																	0	0.0
Total	51	24	2	6	4	1	1	1	5	1	0	0	0	0	0	0	96	100.0
%Tot	53.1	25.0	2.1	6.3	4.2	1.0	1.0	1.0	5.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B3: Journal Citations of Leveson (1995) by Numbers of Citing European (Excluding UK and Ireland) Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth		
1995																	0	0.0
1996	7																7	10.9
1997		1								1							2	3.1
1998	4																4	6.3
1999	9				1				2								12	18.8
2000	8	2		5													15	23.4
2001	2	4		2						2							10	15.6
2002	1	2		3						2							8	12.5
2003	6																6	9.4
Total	37	9	0	10	1	0	0	0	2	5	0	0	0	0	0	0	64	100.0
%Tot	57.8	14.1	0.0	15.6	1.6	0.0	0.0	0.0	3.1	7.8	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B4: Journal Citations of Leveson (1995) by Numbers of Citing All Other Countries Authors

	Academic				Government				Commercial				Other & Non-Ident.					
	Com	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Total**	**% of Total**
1995																	0	0.0
1996																	0	0.0
1997	4	2															6	17.6
1998	2	9							1								12	35.3
1999										3							3	8.8
2000	5																5	14.7
2001																	0	0.0
2002				1						1							2	5.9
2003	4	2															6	17.6
Total	15	13	0	1	0	0	0	0	1	4	0	0	0	0	0	0	34	100.0
%Tot	44.1	38.2	0.0	2.9	0.0	0.0	0.0	0.0	2.9	11.8	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B5: Geographic Areas of Journal Citations of Leveson (1995) by Numbers of Citing Authors

	NA	**OE**	**EU**	**AO**	**Total**	**% of Total**
1995	1				1	0.4
1996	2	4	7		13	4.9
1997	4	6	2	6	18	6.8
1998	14	18	4	12	48	18.1
1999	12	22	12	3	49	18.5
2000	19	31	15	5	70	26.4
2001	2	10	10		22	8.3
2002	12	5	8	2	27	10.2
2003	5		6	6	17	6.4
Total	71	96	64	34	265	100.0
%Tot	26.8	36.2	24.2	12.8	100.0	

Table B6: Affiliations of Journal Citations of Leveson (1995) by Numbers of Citing Authors

	Acad	**Govt**	**Comm**	**Other**	**Total**	**% of Total**
1995			1		1	0.4
1996	13				13	4.9
1997	13	1	4		18	6.8
1998	36	4	7	1	48	18.1
1999	37	3	8	1	49	18.5
2000	63	3	4		70	26.4
2001	13		9		22	8.3
2002	19	1	7		27	10.2
2003	15		2		17	6.4
Total	209	12	42	2	265	100.0
%Tot	78.9	4.5	15.8	0.8	100.0	

Table B7: Subject Areas of Journal Citations of Leveson (1995) by Numbers of Citing Authors

	Com	Eng	Med	Oth	Total	% of Total
1995	1				1	0.4
1996	13				13	4.9
1997	9	8		1	18	6.8
1998	30	16	2		48	18.1
1999	35	14			49	18.5
2000	45	16	1	8	70	26.4
2001	8	8	1	5	22	8.3
2002	7	15	1	4	27	10.2
2003	10	2	5		17	6.4
Total	158	79	10	18	265	100.0
%Tot	59.6	29.8	3.8	6.8	100.0	

Table B8: Number of Different Authors Citing Leveson (1995) by Geographic Area

	Number of Citing Articles Authored Per Author					Percentage of Grand Total				
	1	**2**	**3**	**>3**	**Total**	**1**	**2**	**3**	**>3**	**Total**
NA	60	7	3	1	71	26.8	3.1	1.3	0.4	31.7
OE	60	8	0	1	69	26.8	3.6	0.0	0.4	30.8
EU	42	11	0	0	53	18.8	4.9	0.0	0.0	23.7
AO	29	2	0	0	31	12.9	0.9	0.0	0.0	13.8
Total	191	28	3	2	224	85.3	12.5	1.3	0.9	100.0

Table B9: Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing North American Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**	**Com**	**Eng**	**Med**	**Oth**		
1995									1								1	1.5
1996	2																2	3.0
1997	2	1							1	1							5	7.6
1998	4	1	1		2				3	2				1			14	21.2
1999	7	1							1	2			1				12	18.2
2000	6	4			1	1			4								16	24.2
2001		1									1						2	3.0
2002	2	3			1					3	1						10	15.2
2003			2								2						4	6.1
Total	23	11	3	0	4	1	0	0	10	8	4	0	1	1	0	0	66	100.0
%Tot	34.8	16.7	4.5	0.0	6.1	1.5	0.0	0.0	15.2	12.1	6.1	0.0	1.5	1.5	0.0	0.0	100.0	

Table B10: Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing Other English Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth		
1995																	0	0.0
1996	3																3	6.3
1997	1	1								1							3	6.3
1998	6	1	1														8	16.7
1999	4	3				1											8	16.7
2000	8	4		2					1								15	31.3
2001	1			3							1	1					6	12.5
2002	3	2															5	10.4
2003																	0	0.0
Total	26	11	1	5	0	1	0	0	1	1	1	1	0	0	0	0	48	100.0
%Tot	54.2	22.9	2.1	10.4	0.0	2.1	0.0	0.0	2.1	2.1	2.1	2.1	0.0	0.0	0.0	0.0	100.0	

Table B11: Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing European (excluding UK and Ireland) Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth		
1995																	0	0.0
1996	2																2	5.3
1997										1							1	2.6
1998	3																3	7.9
1999	5				1				1								7	18.4
2000	5	1		5													11	28.9
2001	1	2		1						1							5	13.2
2002	1	2		1						2							8	15.8
2003	3																3	7.9
Total	20	5	0	7	1	0	0	0	1	4	0	0	0	0	0	0	38	100.0
%Tot	52.6	13.2	0.0	18.4	2.6	0.0	0.0	0.0	2.6	10.5	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B12: Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing All Other Countries Authors

	Academic				Government				Commercial				Other & Non-Ident.				Total	% of Total
	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth	Com	Eng	Med	Oth		
1995																	0	0.0
1996																	0	0.0
1997	2	2															4	21.1
1998	2	1							1								4	21.1
1999		1								1							2	10.5
2000	4																4	21.1
2001										1							1	5.3
2002				1													1	5.3
2003	2	1															3	15.8
Total	10	5	0	1	0	0	0	0	1	2	0	0	0	0	0	0	19	100.0
%Tot	52.6	26.3	0.0	5.3	0.0	0.0	0.0	0.0	5.3	10.5	0.0	0.0	0.0	0.0	0.0	0.0	100.0	

Table B13: Geographic Areas of Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing Authors

	NA	OE	EU	AO	Total	% of Total
1995	1				1	0.6
1996	2	3	2		7	4.1
1997	5	3	1	4	13	7.6
1998	14	8	3	4	29	17.0
1999	12	8	7	2	29	17.0
2000	16	15	11	4	46	26.9
2001	2	6	5	1	14	8.2
2002	10	5	6	1	22	12.9
2003	4		3	3	10	5.8
Total	66	48	38	19	171	100.0
%Tot	38.6	28.1	22.2	11.1	100.0	

Table B14: Affiliations of Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing Authors

	Acad	Govt	Comm	Other	Total	% of Total
1995			1		1	0.6
1996	7				7	4.1
1997	9		4		13	7.6
1998	20	2	6	1	29	17.0
1999	21	2	5	1	29	17.0
2000	39	2	5		46	26.9
2001	9		5		14	8.2
2002	15	1	6		22	12.9
2003	8		2		10	5.8
Total	128	7	34	2	171	100.0
%Tot	74.9	4.1	19.9	1.2	100.0	

Table B15: Subject Areas of Journal Citations of Leveson (1995) by Numbers of Affiliations of Citing Authors

	Comp	Eng	Med	Oth	Total	% of Total
1995	1				1	0.6
1996	7				7	4.1
1997	6	7			13	7.6
1998	21	6	2		29	17.0
1999	20	9			29	17.0
2000	29	10		7	46	26.9
2001	2	5	2	5	14	8.2
2002	7	12	1	2	22	12.9
2003	5	1	4		10	5.8
Total	98	50	9	14	171	100.0
%Tot	57.3	29.2	5.3	8.2	100.0	

Table B16: Number of Different Organisational Affiliations of Authors Citing Leveson (1995) by Geographic Area (with Affiliation Equalling Organisational Sub-Unit)

	Number of Citing Articles Per Organisation					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
NA	46	9	2		57	32.6	6.4	1.4		40.4
OE	23	6	2	1	32	16.3	4.3	1.4	0.7	22.7
EU	27	7			34	19.1	5.0			24.1
AO	17	1			18	12.1	0.7			12.8
Total	113	23	4	1	141	80.1	16.3	2.8	0.7	100.0

Table B17: Number of Different Organisational Affiliations of Authors Citing Leveson (1995) by Geographic Area (with Affiliation Equalling the Overall Organisational)

	Number of Citing Articles Per Organisation					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
NA	36	9	2	1	48	30.3	7.6	1.7		40.3
OE	18	5	3	2	28	15.1	4.2	2.5	1.7	23.5
EU	24	6	1		31	20.2	5.0			26.1
AO	7	4	1		12	5.9	3.4			10.1
Total	85	24	7	3	119	71.4	20.2	4.2	1.7	100.0

Table B18: Number of Articles Citing Leveson (1995) by Subject of the Citing Articles

	Com	Eng	Med	Other	Total	% of Total
1995	1				1	0.8
1996	4				4	3.4
1997	5	5			10	8.4
1998	10	4	2		16	13.4
1999	17	7			24	20.2
2000	19	7		5	31	26.1
2001	2	4	2	3	11	9.2
2002	6	7	1	2	16	13.4
2003	3	1	2		6	5.0
Total	67	35	7	10	119	100.0
%Tot	56.3	29.4	5.9	8.4	100.0	

Table B19: Number of Citations of Articles Citing Leveson (1995) by Subject of the Citing Articles

	Com	Eng	Med	Other	Total	% of Total
1995						0.0
1996	33				33	22.4
1997	6	27			33	22.4
1998	25	4	3		32	21.8
1999	18	1			19	12.9
2000	13	8		5	26	17.7
2001	1				1	0.7
2002	1	1	1		3	2.0
2003					0	0.0
Total	97	41	4	5	147	100.0
%Tot	66.0	27.9	2.7	3.4	100.0	

Table B20: Average Number of Citations of Articles Citing Leveson (1995) by Subject of the Citing Articles

	Com	Eng	Med	Other	Total
1995	0.00	na	na	na	0.00
1996	8.25	na	na	na	8.25
1997	1.20	5.40	na	na	6.60
1998	2.50	1.00	1.50	na	5.00
1999	1.06	0.14	na	na	1.20
2000	0.68	1.14	na	1.00	2.83
2001	0.50	0.00	0.00	0.00	0.50
2002	0.17	0.14	1.00	0.00	1.31
2003	0.00	0.00	0.00	na	0.00
Total	1.45	1.17	0.57	0.50	1.24

Table B21: Number of Authors Per Computing Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995		1			1	0.0	1.5	0.0	0.0	1.5
1996		3		1	4	0.0	4.5	0.0	1.5	6.0
1997	1	3	1		5	1.5	4.5	1.5	0.0	7.5
1998	3	2	2	3	10	4.5	3.0	3.0	4.5	14.9
1999	7	7	1	2	17	10.4	10.4	1.5	3.0	25.4
2000	6	5	5	3	19	9.0	7.5	7.5	4.5	28.4
2001	1	1			2	1.5	1.5	0.0	0.0	3.0
2002	4	2			6	6.0	3.0	0.0	0.0	9.0
2003		1		2	3	0.0	1.5	0.0	3.0	4.5
Total	22	25	9	11	67	32.8	37.3	13.4	16.4	100.0

Table B22: Number of Authors Per Engineering Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997	2	2	1		5	5.7	5.7	2.9	0.0	14.3
1998	1	1		2	4	2.9	2.9	0.0	5.7	11.4
1999	4		2	1	7	11.4	0.0	5.7	2.9	20.0
2000	2	2	2	1	7	5.7	5.7	5.7	2.9	20.0
2001	2	1	1		4	5.7	2.9	2.9	0.0	11.4
2002	2	3	1	1	7	5.7	8.6	2.9	2.9	20.0
2003		1			1	0.0	2.9	0.0	0.0	2.9
Total	13	10	7	5	35	37.1	28.6	20.0	14.3	100.0

Table B23: Number of Authors Per Medical Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997					0	0.0	0.0	0.0	0.0	0.0
1998	2				2	28.6	0.0	0.0	0.0	28.6
1999					0	0.0	0.0	0.0	0.0	0.0
2000					0	0.0	0.0	0.0	0.0	0.0
2001	1			1	2	14.3	0.0	0.0	14.3	28.6
2002	1				1	14.3	0.0	0.0	0.0	14.3
2003		1	1		2	0.0	14.3	14.3	0.0	28.6
Total	4	1	1	1	7	57.1	14.3	14.3	14.3	100.0

Table B24: Number of Authors Per Other Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997					0	0.0	0.0	0.0	0.0	0.0
1998					0	0.0	0.0	0.0	0.0	0.0
1999					0	0.0	0.0	0.0	0.0	0.0
2000	3	1	1		5	30.0	10.0	10.0	0.0	50.0
2001	1	2			3	10.0	20.0	0.0	0.0	30.0
2002	1		1		2	10.0	0.0	10.0	0.0	20.0
2003					0	0.0	0.0	0.0	0.0	0.0
Total	5	3	2	0	10	50.0	30.0	20.0	0.0	100.0

Table B25: Number of Authors Per Article Citing Leveson (1995) for All Subjects

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995		1			1	0.0	0.8	0.0	0.0	0.8
1996		3		1	4	0.0	2.5	0.0	0.8	3.4
1997	3	5	2		10	2.5	4.2	1.7	0.0	8.4
1998	6	3	2	5	16	5.0	2.5	1.7	4.2	13.4
1999	11	7	3	3	24	9.2	5.9	2.5	2.5	20.2
2000	11	8	8	4	31	9.2	6.7	6.7	3.4	26.1
2001	5	4	1	1	11	4.2	3.4	0.8	0.8	9.2
2002	8	5	2	1	16	6.7	4.2	1.7	0.8	13.4
2003		3	1	2	6	0.0	2.5	0.8	1.7	5.0
Total	44	39	19	17	119	37.0	32.8	16.0	14.3	100.0

Table B26: Number of Affiliations Per Computing Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995	1				1	1.5	0.0	0.0	0.0	1.5
1996	1	3			4	1.5	4.5	0.0	0.0	6.0
1997	4	1			5	6.0	1.5	0.0	0.0	7.5
1998	3	5		2	10	4.5	7.5	0.0	3.0	14.9
1999	14	3			17	20.9	4.5	0.0	0.0	25.4
2000	12	5	1	1	19	17.9	7.5	1.5	1.5	28.4
2001	2				2	3.0	0.0	0.0	0.0	3.0
2002	5	1			6	7.5	1.5	0.0	0.0	9.0
2003	1	2			3	1.5	3.0	0.0	0.0	4.5
Total	43	20	1	3	67	64.2	29.9	1.5	4.5	100.0

Table B27: Number of Affiliations Per Engineering Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997	2	3			5	5.7	8.6	0.0	0.0	14.3
1998	3		1		4	8.6	0.0	2.9	0.0	11.4
1999	5	1	1		7	14.3	2.9	2.9	0.0	20.0
2000	4	3			7	11.4	8.6	0.0	0.0	20.0
2001	3		1		4	8.6	0.0	2.9	0.0	11.4
2002	4	1	1	1	7	11.4	2.9	2.9	2.9	20.0
2003	1				1	2.9	0.0	0.0	0.0	2.9
Total	22	8	4	1	35	62.9	22.9	11.4	2.9	100.0

Table B28: Number of Affiliations Per Medical Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997					0	0.0	0.0	0.0	0.0	0.0
1998	2				2	28.6	0.0	0.0	0.0	28.6
1999					0	0.0	0.0	0.0	0.0	0.0
2000					0	0.0	0.0	0.0	0.0	0.0
2001	2				2	28.6	0.0	0.0	0.0	28.6
2002	1				1	14.3	0.0	0.0	0.0	14.3
2003		2			2	0.0	28.6	0.0	0.0	28.6
Total	5	2	0	0	7	71.4	28.6	0.0	0.0	100.0

Table B29: Number of Affiliations Per Other Article Citing Leveson (1995)

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995					0	0.0	0.0	0.0	0.0	0.0
1996					0	0.0	0.0	0.0	0.0	0.0
1997					0	0.0	0.0	0.0	0.0	0.0
1998					0	0.0	0.0	0.0	0.0	0.0
1999					0	0.0	0.0	0.0	0.0	0.0
2000	4		1		5	40.0	0.0	10.0	0.0	50.0
2001	1	1	1		3	10.0	10.0	10.0	0.0	30.0
2002	2				2	20.0	0.0	0.0	0.0	20.0
2003					0	0.0	0.0	0.0	0.0	0.0
Total	7	1	2	0	10	70.0	10.0	20.0	0.0	100.0

Table B30: Number of Affiliations Per Article Citing Leveson (1995) for All Subjects

	Number					Percentage of Grand Total				
	1	2	3	>3	Total	1	2	3	>3	Total
1995	1				1	0.8	0.0	0.0	0.0	0.8
1996	1	3			4	0.8	2.5	0.0	0.0	3.4
1997	6	4			10	5.0	3.4	0.0	0.0	8.4
1998	8	5	1	2	16	6.7	4.2	0.8	1.7	13.4
1999	19	4	1		24	16.0	3.4	0.8	0.0	20.2
2000	20	8	2	1	31	16.8	6.7	1.7	0.8	26.1
2001	8	1	2		11	6.7	0.8	1.7	0.0	9.2
2002	12	2	1	1	16	10.1	1.7	0.8	0.8	13.4
2003	2	4			6	1.7	3.4	0.0	0.0	5.0
Total	77	31	7	4	119	64.7	26.1	5.9	3.4	100.0

Table B31: Number of Countries by Affiliations Per Computing Article Citing Leveson (1995)

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995	1				1	1.5				1.5				0				0.0
1996	4				4	6.0				6.0				0				0.0
1997	5				5	7.5				7.5				0				0.0
1998	7	3			10	10.4	4.5			14.9	3			3	4.5			4.5
1999	17				17	25.4				25.4				0				0.0
2000	16	2	1		19	23.9	3.0	1.5		28.4	2	1		3	3.0	1.5		4.5
2001	2				2	3.0				3.0				0				0.0
2002	6				6	9.0				9.0				0				0.0
2003	3				3	4.5				4.5				0				0.0
Total	61	5	1	0	67	91.0	7.5	1.5	0.0	100.0	5	1	0	6	7.5	1.5	0.0	9.0

Table B32: Number of Countries by Affiliations Per Engineering Article Citing Leveson (1995)

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995					0					0.0				0				0.0
1996					0					0.0				0				0.0
1997	4	1			5	11.4	2.9			14.3		1		1		2.9		2.9
1998	4				4	11.4				11.4				0				0.0
1999	7				7	20.0				20.0				0				0.0
2000	7				7	20.0				20.0				0				0.0
2001	4				4	11.4				11.4				0				0.0
2002	5	2			7	14.3	5.7			20.0	1	1		2	2.9	2.9		5.7
2003	1				1	2.9				2.9				0				0.0
Total	32	3	0	0	35	91.4	8.6	0.0	0.0	100.0	1	2	0	3	2.9	5.7	0.0	8.6

Table B33: Number of Countries by Affiliations Per Medical Article Citing Leveson (1995)

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995					0					0.0				0				0.0
1996					0					0.0				0				0.0
1997					0					0.0				0				0.0
1998	2				2	28.6				28.6				0				0.0
1999					0					0.0				0				0.0
2000					0					0.0				0				0.0
2001	2				2	28.6				28.6				0				0.0
2002	1				1	14.3				14.3				0				0.0
2003	1	1			2	14.3	14.3			28.6		1		1		14.3		14.3
Total	6	1	0	0	7	85.7	14.3	0.0	0.0	100.0	0	1	0	1	0.0	14.3	0.0	14.3

Table B34: Number of Countries by Affiliations Per Medical Article Citing Leveson (1995)

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995					0					0.0				0				0.0
1996					0					0.0				0				0.0
1997					0					0.0				0				0.0
1998					0					0.0				0				0.0
1999					0					0.0				0				0.0
2000	4	1			5	40.0	10.0			50.0			1	1			10.0	10.0
2001	3				3	30.0				30.0				0				0.0
2002	2				2	20.0				20.0				0				0.0
2003					0					0.0				0				0.0
Total	9	1	0	0	10	90.0	10.0	0.0	0.0	100.0	0	0	1	1	0.0	0.0	10.0	10.0

Table B35: Number of Countries by Affiliations Per Article Citing Leveson (1995) for All Subjects

	Number					Percentage of Grand Total					Number				% of Grand Total			
	1	2	3	>3	Total	1	2	3	>3	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total	Engl & Non Engl	Engl & Engl	Non Engl &Non Engl	Total
1995	1				1	0.8				0.8				0				0.0
1996	4				4	3.4				3.4				0				0.0
1997	9	1			10	7.6	0.8			8.4		1		1		0.8		1.5
1998	13	3			16	10.9	2.5			13.4	3			3	2.5			4.5
1999	24				24	20.2				20.2				0				0.0
2000	27	3	1		31	22.7	2.5	0.8		26.1	2	1	1	4	1.7	0.8	0.8	6.0
2001	11				11	9.2				9.2				0				0.0
2002	14	2			16	11.8	1.7			13.4	1	1		2	0.8	0.8		3.0
2003	5	1			6	4.2	0.8			5.0		1		1		0.8		1.5
Total	108	10	1	0	119	90.8	8.4	0.8	0.0	100.0	6	4	1	11	5.0	3.4	0.8	9.2