高等教育安全科学与工程类系列规划教材
高等院校安全工程类特色专业系列规划教材

TESE ZHUANYE XILIE

安全工程专业英语

主编　黄志安　张英华

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本书共20个单元，其中的科技英语文章均按安全科学与工程学科所涉及的领域选取，涵盖施工安全、食品安全、矿井安全、特种设备安全、安全评价与风险管理、应急救援等多个方面。本书每个单元主要由课文和相应的阅读材料组成，其后都附有生词和短语注解，还编入了练习题，方便读者理解与学习。每个单元还单独设置一个模块，介绍了科技英语的阅读方法和技巧、科技英语的语言特点，以及科技英语的翻译技巧，同时列举了大量的例句，有助于理解与掌握；对科技英语写作要点进行了简单介绍，并列举了科技英语写作中的常用句型。

本书内容广泛，形式新颖，主要作为高等院校安全科学与工程类专业英语本科教材，也可作为安全工程技术和管理人员的学习参考用书。

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安全科学与工程类专业教材
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序

“安全工程”本科专业是在1958年建立的“工业安全技术”“工业卫生技术”和1983年建立的“矿山通风与安全”本科专业基础上发展起来的。1984年，国家教委将“安全工程”专业作为试办专业列入普通高等学校本科专业目录之中。1998年7月6日，教育部发文颁布了《普通高等学校本科专业目录》，“安全工程”本科专业（代号：081002）属于工学门类的“环境与安全类”（代号：0810）学科下的两个专业之一㊀。1958～1996年年底，全国各高校累计培养安全工程专业本科生8130人。到2005年年底，在教育部备案的设有安全工程本科专业的高校已达75所，2005年全国安全工程专业本科招生人数近3900名㊁。

按照《普通高等学校本科专业目录》的要求，以及院校招生和专业发展的需要，原来已设有与“安全工程”专业相近但专业名称有所差异的高校，现也大都更名为“安全工程”专业。专业名称统一后的“安全工程”专业，专业覆盖面大大拓宽㊀。同时，随着经济社会发展对安全工程专业人才要求的更新，安全工程专业的内涵也发生了很大变化，相应的专业培养目标、培养要求、主干学科、主要课程、主要实践性教学环节等都有了不同程度的变化，学生毕业后的执业身份是注册安全工程师。但是，安全工程专业的教材建设与专业的发展出现尚不适应的新情况，无法满足和适应高等教育培养人才的需要。为此，组织编写、出版一套新的安全工程专业系列教材已成为众多院校的翘首之盼。

机械工业出版社是有着悠久历史的国家级优秀出版社，在高等学校安全工程学科教学指导委员会的指导和支持下，根据当前安全工程专业教育的发展现状，本着“大安全”的教育思想，进行了大量的调查研究工作，聘请了安全科学与工程领域一批学术造诣深厚、实践经验丰富的教授和专家，组织成立了“安全工程专业教材编审委员会”（以下简称“编审委”），决定组织编写“高等教育安全工程系列‘十一五’规划教材”㊂，并先后于2004年8月（衡阳）、2005年8月（葫芦岛）、2005年12月（北京）、2006年4月（福州）组织召开了一系列安全工程专业本科教材建设研讨会，就安全工程专业本科教育的课程体系、课程教学内容、教材建设等问题反复进行了研讨，在总结以往教学改革、教材编写经验的基础上，以推动安全工程专业教学改革和教材建设为宗旨，进行顶层设计，

㊀ 按《普通高等学校本科专业目录》（2012版），“安全工程”本科专业（专业代码：082901）属于工学学科的“安全科学与工程类”（专业代码：0829）下的专业。

㊁ 各高校安全工程本科每年的招生数量可以通过高等学校安全工程学科教学指导委员会主办的“全国高等院校安全工程学科教育数据和信息系统”查询（www. cosha. org. cn）。

㊂ 自2012年更名为“高等教育安全科学与工程类系列规划教材”。

制订总体规划、出版进度和编写原则，计划分期分批出版30余门课程的教材，以尽快满足全国众多院校的教学需要，以后再根据专业方向的需要逐步增补。

由安全学原理、安全系统工程、安全人机工程学、安全管理学等课程构成的学科基础平台课程，已被安全科学与工程领域学者认可并达成共识。本套系列教材编写、出版的基本思路是，在学科基础平台上，构建支撑安全工程专业的工程学原理与由关键性的主体技术组成的专业技术平台课程体系，编写和出版系列教材来支撑这个体系。

本套系列教材体系设计的原则是，重基本理论，重学科发展，理论联系实际，结合学生现状，体现人才培养要求。为保证教材的编写质量，本着“主编负责，主审把关”的原则，编审委组织专家分别对各门课程教材的编写大纲进行认真仔细的评审。教材初稿完成后又组织同行专家对书稿进行研讨，编者数易其稿，经反复推敲定稿后才最终进入出版流程。

作为一套全新的安全工程专业系列教材，其“新”主要体现在以下几点：

体系新。本系列教材从“大安全”的专业要求出发，从整体上考虑、构建支撑安全工程学科专业技术平台的课程体系和各门课程的内容安排，按照教学改革方向要求的学时，统一协调与整合，形成一个完整的、各门课程之间有机联系的系列教材体系。

内容新。本系列教材的突出特点是内容体系上的创新。它既注重知识的系统性、完整性，又特别注意各门学科基础平台课之间的关联，更注意后续的各门专业技术课与先修的学科基础平台课的衔接，充分考虑了安全工程学科知识体系的连贯性和各门课程教材间知识点的衔接、交叉和融合问题，努力消除相互关联课程中内容重复的现象，突出安全工程学科的工程学原理与关键性的主体技术，有利于学生的知识和技能的发展，有利于教学改革。

知识新。本套系列教材的主编大多由长期从事安全工程专业本科教学的教授担任，他们一直处于教学和科研的第一线，学术造诣深厚，教学经验丰富。在编写教材时，他们十分重视理论联系实际，注重引入新理论、新知识、新技术、新方法、新材料、新装备、新法规等理论研究、工程技术实践成果和各校教学改革的阶段性成果，充实与更新了知识点，增加了部分学科前沿方面的内容，充分体现了教材的先进性和前瞻性，以适应时代对安全工程高级专业技术人才的培育要求。本套系列教材中凡涉及安全生产的法律法规、技术标准、行业规范，全部采用最新颁布的版本。

安全是人类最重要和最基本的需求，是人民生命与健康的基本保障。一切生活、生产活动都源于生命的存在。如果人们失去了生命，一切都无从谈起。全世界平均每天发生约68.5万起事故，造成约2200人死亡的事实，使我们确认，安全不是别的什么，安全就是生命。安全生产是社会文明和进步的重要标志，是经济社会发展的综合反映，是落实以人为本的科学发展观的重要实践，是构建和谐社会的有力保障，是全面建成小康社会、统筹经济社会全面发展的重要内容，是实施可持续发展战略的组成部分，是各级政府履行市场监管和社会管理职能的基本任务，是企业生存、发展的基本要求。国内外实践证明，安全生产具有全局性、社会性、长期性、复杂性、科学性和规律性的特点，随着社会的不断进步，工业化进程的加快，安全生产工作的内涵发生了重大变化，它突破了时间和空间的限制，存在于人们日常生活和生产活动的全过程中，成为一个复杂多变的社会问题在安全领

域的集中反映。安全问题不仅对生命个体非常重要，而且对社会稳定和经济发展产生重要影响。党的十六届五中全会提出“安全发展”的重要战略理念。安全发展是科学发展观理论体系的重要组成部分，安全发展与构建和谐社会有着密切的内在联系，以人为本，首先就是要以人的生命为本。“安全·生命·稳定·发展”是一个良性循环。安全科技工作者在促进、保证这一良性循环中起着重要作用。安全科技人才匮乏是我国安全生产形势严峻的重要原因之一。加快培养安全科技人才也是解开安全难题的钥匙之一。

高等院校安全工程专业是培养现代安全科学技术人才的基地。我深信，本套系列教材的出版，将对我国安全工程本科教育的发展和高级安全工程专业人才的培养起到十分积极的推进作用，同时，也为安全生产领域众多实际工作者提高专业理论水平提供学习资料。当然，这是第一套基于专业技术平台课程体系的教材，尽管我们的编审者和出版者夙兴夜寐，尽心竭力，但由于安全工程学科具有理论上的综合性与应用上的广泛性相交叉的特性，开办安全工程专业的高等院校所依托的行业类型又涉及军工、航空、化工、石油、矿业、土木、交通、能源、环境、经济等诸多领域，安全工程的应用也涉及人类生产、生活和生存的各个方面，因此本套系列教材依然会存在这样或那样的缺点和不足，难免挂一漏万，诚恳地希望得到有关专家和学者的关心与支持，希望选用本套系列教材的广大师生在使用过程中给我们多提意见和建议。谨祝本系列教材在编者、出版者、授课教师和学生的共同努力下，通过教学实践，获得进一步的完善和提高。

“嘤其鸣矣，求其友声”，高等院校安全工程专业正面临着前所未有的发展机遇，在此我们祝愿各个高校的安全工程专业越办越好，办出特色，为我国安全生产战线输送更多的优秀人才。让我们共同努力，为我国安全工程教育事业的发展做出贡献。

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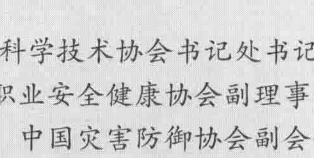

⊖ 曾任中国科协副主席。

前言

安全是人类生存和发展的基本要求，是生命与健康的基本保障。随着科技进步和社会的飞速发展，安全问题越来越受到社会的关注。为了减少意外事故，保障安全、健康的生产条件和作业环境，形成了安全科学与工程学科。

随着经济全球化的推进，安全工程专业英语是安全工程专业的人才所应具备的基本能力，也是了解与借鉴国外安全科学与工程领域先进技术的重要工具。希望通过本书能够提高安全工程专业人才的专业英语能力。本书的编写与出版得到了北京科技大学教材建设经费的资助。

本书是在借鉴国内外同类教材的基础上，为适应新的教学改革需要而编写的。全书内容广泛，共20个单元，系统地介绍了安全科学与工程学科的相关内容，使读者对该学科有更清晰的认识。同时为提高读者的专业英语水平，系统地介绍了科技英语的翻译与写作技巧。

本书由北京科技大学土木与资源工程学院安全科学与工程系黄志安、张英华担任主编，高玉坤、王辉任副主编；具体编写分工如下：黄志安、孙传武和王树祎编写1~5单元和附录，高玉坤和孙传武编写6~10单元，张英华、孙传武和张歌编写11~15单元，王辉、杨锐和燕立凯编写16~20单元。

本书由黄志安统稿，北京科技大学土木与资源工程学院的金龙哲教授和中国矿业大学(北京)的王凯教授担任主审，两位教授对本书进行了全面、细致的审阅，提出了许多宝贵的修改意见和建议。在此对两位教授的辛勤工作表示衷心感谢！

本书在编写过程中参考了国内外安全理论、矿山安全、工业安全相关的科技文献和书目，以及相关的科技英语翻译与写作的书目，在此对原作者表示诚挚的谢意。

由于编者的学识水平有限，书中难免有不当与错误之处，敬请广大读者及相关专家批评指正。

编 者

目 录

Unit One

Text

Safety Theory

Despite an enormous amount of effort and resources applied to security in recent years, significant progress seems to be lacking. Similarly, changes in engineering are making traditional safety analysis techniques increasingly less effective. Most of these techniques were created over 50 years ago when systems were primarily composed of electromechanical components and were orders of magnitude less complex than today's software-intensive systems. New, more powerful safety analysis techniques, based on systems theory, are being developed and successfully used on a large variety of systems today, including aircraft, spacecraft, nuclear power plants, automobiles, medical devices, and so forth. Systems theory can, in the same way, provide a powerful foundation for security. An additional benefit is the potential for creating an integrated approach to both security and safety.

1. *Accident Causation Analysis and Taxonomy (ACAT) Model*

Since the concepts of man-machine-media model was first proposed by T. P. Wright, it has had a profound effect on accident analysis and prevention. Afterward, Management and Mission were introduced and the 5M model was established. In consideration of the complexity of system failure, more system factors have been incorporated into 5M model. For instance, Miller summarized seven system safety factors, which are man, machine, media, management, time, cost, and information. Irani et al. proposed a variation "5M" model to evaluate the impact of human, process and technology factors on information system failure. Kozuba suggested that though many efforts had been made to prevent undesirable flight-related events, human factor, technical factor and organizational factor were still the main causes. Of all these systematic safety factor models, the initial 5M model is the most widely used one and has been generally accepted in many areas, especially in ***aviation*** domains. It is a structured method which describes the subjects of safety analysis.

For a long time, man, machine, media, management, and mission have been recognized as the main elements contributing to accidents. However, it is too ***vague*** to include failures caused by supervision, decision making, regulations, or safety attitudes into management failure. Traditional management factor is a general subject which cannot provide more detailed types of failure. Based on accidents review, we identified six system safety factors, which are Man (M), Machine (M), Management (M), Environment (E), Information (I), and Resources (R). Among these system safety factors, machine refers to hardware in plant including all kinds of instruments, equipment, or vehicles. Man, which is also called human, refers to on-site personnel like operator, maintenance worker, office stuff, installer, or field supervisor. Their duties are to implement the decisions from managers. Management refers to supervision or decisions made by managers from plant units, companies, agencies, or government. Information includes procedures, programs, methods, standards, regulations, or laws. Resources include training, experts, raw materials, fund, energy, or products. Environment does not mean the physical environment but a social environment because the physical environment like weather is beyond controllability. It usually includes safety culture, attitude, or issues left over by history. Take BP Texas ***refinery*** accident as an example, inadequate preliminary hazard analysis and mechanical integrity program are categorized into information failure. To prevent this type of failure, attention should be paid to program formulation and evaluation.

Different considerations are defined for each factor of the system to detail its potential risks. However, due to lack of standards for the interpretation of these factors, different reference presents varied considerations. It leads to poor consistency in application. Hence, a structured theory is needed to guide the establishment of subgroups. Control theory can describe factors' functions and their communications with a closed loop. Each component in a control structure indicates a particular function that one factor should complete. A simplified diagram of a control structure is shown in Figure 1-1.

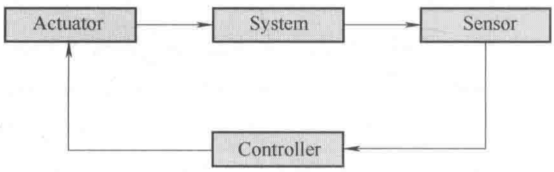

Figure 1-1 Simplified Diagram of a Control Structure

The basic components are actuator, sensor, and controller and communication, respectively. Therefore, from the perspective of control theory, it is assumed that each system safety factor has these four functional characteristics. The definitions of the functional characteristics are shown in Table 1-1. For example, if the mission is to open a valve, the control system can be described as follows: ① an operator who open the valve is actuator of the mission, ② sensor refers to the field supervisor whose job is to monitor the operation process, ③ an audit or evaluation should be made by a controller, and ④ all of these works require effective communications. Any missing function may ***lead to*** mission failure.

Table 1-1 Definitions of Control System Factors

Functional Factor	Function Definition
Actuator	Take measures or execute commands
Sensor	Measure and monitor the output
Controller	Compare output performance with the reference
→ Communication	Connect elements and convey information

To address the basic two issues of accident analysis, which are ① what is the failure and ② how does the failure happen, a new model is presented from both system safety perspective and control theory perspective. First, complex systems can be decomposed into six components, which are man, machine, management, information, resources, and environment from the view of system safety factors. From control theory perspective, actuator, sensor, controller, and communication are defined as system factors' functional abstractions. The combinations of system factors and control functions form a matrix model for accident ***causation*** analysis and classification, named Accident Causation Analysis and Taxonomy (ACAT) model. Then a comparison with existing cause classification schemes is made and the case of BP Texas refinery accident is used to illustrate its capability (see Table 1-2).

Table 1-2 ACAT Model and Elements' Definitions

Subject ➡ ⬇ Function	Actuator (A)	Sensor (S)	Controller (C)	Communication (O)
Man (M)	H 11	H 12	H 13	H 14
Machine (M)	H 21	H 22	H 23	H 24
Management (M)	H 31	H 32	H 33	H 34
Information (I)	H 41	H 42	H 43	H 44
Resources (R)	H 51	H 52	H 53	H 54
Environment (E)	H 61	H62	H 63	H 64

No.	Description	No.	Description
H11	Fail to take effective actions	H41	Wrong or inadequate information
H12	Fail to monitor, or fail to detect the human failure in time	H42	Fail to monitor or update information
H13	Fail to follow procedures	H43	Fail to establish information
H14	Lack of effective communication between operators	H44	Fail to deliver or interpret information
H21	Design deficiency or malfunction	H51	Lack of training experts, raw materials, fund, energy or products
H22	Fail to monitor or detect the machine failure in time	H52	Fail to monitor the resource spending or changes
H23	Lack of sufficient machine maintenance	H53	Inadequate allocation of resources
H24	Information from equipment is not captured or interpreted	H54	Fail to deliver resources or resources needs
H31	Fail to manage workers or equipment or organization appropriately	H61	Ignore warnings or issues in previous events
H32	Fail to monitor organizational failure or manage change	H62	Fail to monitor the environment change
H33	Fail to follow procedure organizational inadequate decision	H63	No response to poor safety culture or attitude
H34	Lack of communication within decision levels	H64	Lack of communication culture

2. Reason's Swiss Cheese Model of Accident Causation

The systems approach is ***encapsulated*** in Reason's Swiss Cheese model of accident causation. The model states that in any system there are many levels of defense but these defenses are imperfect both because of inherent human ***fallibility*** and weaknesses in how systems are designed and operated.

Reason's model distinguishes between active failures and latent conditions. Active failures are errors and violations that are committed by people at the service delivery end of the system. Active failures by these people may have an immediate impact on safety.

Latent conditions result from poor decisions made by the higher management in an organization, e. g. by regulators, governments, designers, and manufacturers. Latent conditions lead to weaknesses in the organization's defenses, thus increasing the likelihood that when active failures occur they will combine with existing preconditions, breach the system's defenses, and result in an organizational accident. Latent conditions and active failures lead to windows of opportunity in a system's defenses. When these windows of opportunity are aligned across several levels of a system, an accident trajectory is created (see Figure 1-2). The accident trajectory is represented by the penetration of the levels of defense by an arrow. The holes represent latent and active failures that have breached successive levels of defense. When the arrow penetrates all the levels of defense, an adverse event occurs.

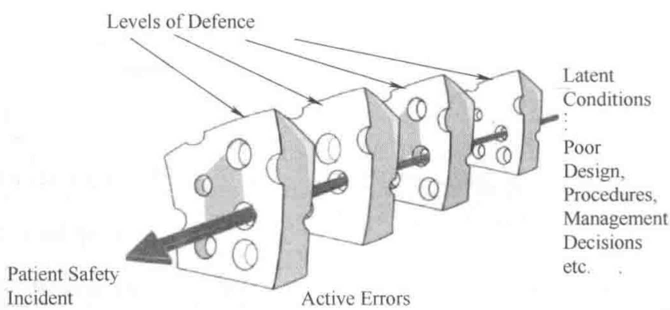

Figure 1-2 Reason's Swiss Cheese Model

3. Beyond Swiss Cheese

The Swiss Cheese model has been used as the theoretical basis for developing other models of incident causation and incident investigation tools in healthcare. The distinction between active and latent failures has strongly influenced efforts to understand the causes of error and incident investigation for the last two decades, both in healthcare and other industries. Its dominance has prevailed even though Reason himself has developed newer models ***aimed at*** understanding human error in complex systems. For example, the three buckets model and the harm absorbers model, both which recognize that healthcare professionals often use ***intuition***, expertise and foresight to anticipate, intervene and prevent patient harm.

4. The Old versus the New View of Human Error

Some critics have argued that, although well-intentioned, in practice, the Swiss Cheese model, leads to a linear approach to incident investigation: in what has been termed the old view of human error, efforts are made to trace back from active errors to identify organizational failures without recognizing the complexity of systems like healthcare and aviation.

Dekker distinguishes between the old view and the new view of human error. He argues that the old view of human error, where there is a search for organizational deficiencies or latent failures, simply causes us to relocate the blame for incidents upstream to senior managers and regulators. This was recently evidenced in the United Kingdom National Health Service in the Francis Inquiry reported into the deaths of patients at Mid Staffordshire hospital. There was a significant focus in both the inquiry report and in subsequent media coverage on the lapses by healthcare regulators that led to delays in intervening to prevent patients being harmed. As a result of the findings of the Francis Inquiry and other high profile national incident reports, the NHS's key regulator, the Care Quality Commission, has come under intense media scrutiny. Dekker's argument that blame is simply attributed further upstream seems, to some extent, to have been borne out by Mid Staffordshire.

Dekker advocates that a new view of human error is needed which views safety as an emergent property of a system in which there are numerous trade-offs between safety and other goals. Other theorists have also recognized that safety is an emergent property in complex systems, including proponents of ***resilience*** engineering.

5. Resilience Engineering

Resilience is the ability of individuals, teams and organizations to identify adapt and absorb variations and surprises on a moment by moment basis. Resilience engineering recognizes that complex systems are dynamic and it is the ability of individuals, teams and organizations to adapt to system changes that creates safety. Resilience moves the focus of learning about safety away from "What went wrong?" to "Why does it go right?".

One key concept from resilience engineering is the distinction between Safety I and Safety II. Safety has traditionally been defined by its absence. That is to say, we learn how to improve safety from investigating past events like incidents, complaints. This is known as Safety I. In contrast, Safety II focuses on the need to learn from what goes right. It involves exploring the ability to succeed when working conditions are dynamic. Safety II involves looking at good outcomes, including how healthcare organizations adapt to drifts and disturbances from a safe state and correct them before an incident occurs. We rarely learn from what goes right because resources are solely invested into learning from what goes wrong. However, serious incidents occur less frequently than instances of Safety II (which are numerous). Hence focusing on what goes right would provide an opportunity to about events that occur frequently, as opposed to rarely.

6. Amalberti's System Migration Model

Amalberti's system migration model is also relevant to understanding errors. Amalberti postulates that humans are naturally adaptable and explore their safety boundaries. A combination of life pressures, perceived vulnerability, belief systems and the trade-off between these factors versus perceived individual benefits leads people to ***navigate*** through the safety space.

Amalberti differentiates between: ① the legal space, i. e. prescribed behavior; ② the illegal-normal space, where people naturally drift into depending on situational factors and personal beliefs; ③ the illegal-illegal space; which brings people into an area of that is unsafe and where the probability of an accident occurring is greatly increased.

The legal-space is defined by policies, procedures and guidelines that describe standards of safe practice. Frequently, when serious incidents occur, non-compliance with policies and procedures is identified as a root cause. All too often hindsight bias comes into play in the investigation process and too little consideration is given to the situational factors that led to non-compliance. Hindsight bias occurs when an investigator, who is looking backwards after an incident has occurred, judges the behavior of those involved unfairly because with the benefit of hindsight it is easy to see the alternative courses of action that could have been taken which would prevent the incident from occurring.

7. Five Lessons about Safety and Accident Causation

Table 1-1 summarizes five lessons from the theories that have been summarized. It is ***postulated*** that future theories of safety need to take account of these five lessons in order to develop models and frameworks that capture the complexity of safety in healthcare. Without an under-pinning theoretical framework that captures how safety is a complex, dynamic phenomenon, healthcare organizations around the world will not understand the different facets of safety that emerge as healthcare systems evolve over time (see Table 1-3).

Table 1-3 Five Key Lessons from Previous Theories of Accident Causation, Human Error, Foresight, Resilience and System Migration

What is the lesson to learn?	Source 1
Lesson 1: A combination of systems and human factors can enhance or erode safely.	Swiss Cheese; Three buckets and harm absorber models
Lesson 2: Systems are dynamic: they evolve over time and spring nasty surprises. Healthcare professionals, teams and organizations sometimes successfully anticipate and manage these nasty surprises, and sometimes they do not.	Three buckets and harm absorber models; Resilience engineering; Safety Ⅰ *versus* Safety Ⅱ
Lesson 3: Safety is an emergent property of the system which needs to be understood in the context of trade-offs with other competing goals (for example, in healthcare, meeting efficiency targets, making financial savings and ensuring continuity of the service).	The old and new view of human error; Resilience engineering
Lesson 4: Hindsight bias, together with the human tendency to attribute blame and the fact that serious incidents occur less frequently than successful outcomes limits what we can learn from taking human error as our starting point and tracing backwards to identify the causes of what went wrong. We therefore need to balance our focus and learn from what goes right rather than being preoccupied with learning from what goes wrong.	The old and new view of human error; Safety Ⅰ *versus* Safety Ⅱ
Lesson 5: Humans migrate and explore the system's safety boundaries. The extent to which they do this depends upon a combination of factors including life pressures, situational factors and personal belief systems.	System migration

8. The Safety Evolution Erosion and Enhancement Model

The five lessons summarized in Table 1-1 are illustrated in Figure 1-2. It shows the underlying processes that

