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**Space systems — Safety  
requirements —**

**Part 1:  
System safety**

*Systèmes spatiaux — Exigences de sécurité —*

*Partie 1: Sécurité système*

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Published in Switzerland

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

This second edition cancels and replaces the first edition (ISO 14620-1:2002), which has been technically revised.

The main changes compared to the previous edition are as follows:

- definitions have been revised; and
- the document has been aligned with the ISO/IEC Directives Part 2, 2016 edition.

A list of all parts in the ISO 14620 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

This document is one of the series of space standards intended to be applied together for the management, engineering and product assurance in space projects and applications.

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# Space systems — Safety requirements —

## Part 1: System safety

### 1 Scope

#### 1.1 General

This document defines the safety programme and the technical safety requirements that are implemented in order to comply with the safety policy as defined in ISO 14300-2. It is intended to protect flight and ground personnel, the launch vehicle, associated payloads, ground support equipment, the general public, public and private property, and the environment from hazards associated with space systems. Launch site operations are described by ISO 14620-2 and flight safety systems in ISO 14620-3.

The safety policy is applied by implementing a system safety programme, supported by risk assessment, which can be summarized as follows.

- a) Hazardous characteristics (system and environmental hazards) and functions with potentially hazardous failure effects are identified and progressively evaluated by iteratively performing systematic safety analyses.
- b) The potential hazardous consequences associated with the system characteristics and functional failures are subjected to a hazard reduction sequence whereby:
  - 1) hazards are eliminated from the system design and operations;
  - 2) hazards are minimized; and
  - 3) hazard controls are applied and verified.
- c) The risks that remain after the application of a hazard elimination and reduction process are progressively assessed and subjected to risk assessment, in order to:
  - 1) show compliance with safety targets;
  - 2) support design trades;
  - 3) identify and rank risk contributors;
  - 4) support apportionment of project resources for risk reduction;
  - 5) assess risk reduction progress; and
  - 6) support the safety and project decision-making process (e.g. waiver approval, residual risk acceptance).
- d) The adequacy of the hazard and risk control measures applied are formally verified in order to support safety validation and risk acceptance.
- e) Safety compliance is assessed by the project and safety approval obtained from the relevant authorities.

## 1.2 Field of application

This document is applicable to all space projects where during any project phase there exists the potential for hazards to personnel or the general public, space flight systems, ground support equipment, facilities, public or private property, or the environment.

The imposition of these requirements on the project suppliers' activities requires that the customer's project product assurance and safety organization also respond to these requirements in a manner which is commensurate with the project's safety criticality.

## 1.3 Tailoring

When viewed from the perspective of a specific programme or project context, the requirements defined in this document are tailored to match the genuine requirements of a particular profile and circumstances of a programme or project.

**NOTE** Tailoring is the process by which individual requirements of specifications, standards and related documents are evaluated, and made applicable to a specific programme or project by selection, and in some exceptional cases, modification of existing or addition of new requirements.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14300-1, *Space systems — Programme management — Part 1: Structuring of a project*

ISO 14300-2, *Space systems — Programme management — Part 2: Product assurance*

ISO 14620-2, *Space systems — Safety requirements — Part 2: Launch site operations*

ISO 14620-3, *Space systems — Safety requirements — Part 3: Flight safety systems*

ISO 24113, *Space systems — Space debris mitigation requirements*

## 3 Terms, definitions and abbreviated terms

### 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

#### 3.1.1

##### **accident**

undesired event arising from operation of any project-specific items which results in:

- a) human death or injury;
- b) loss of, or damage to, hardware, software or facilities which could then affect the accomplishment of the mission;
- c) loss of, or damage to, public or private property; and
- d) detrimental effects on the environment

Note 1 to entry: Accident and mishap are synonymous.

[SOURCE: EN 16601-00-01:2015, 2.3.3]

### 3.1.2

#### **cause**

action or condition by which a hazardous event is initiated (an initiating event)

Note 1 to entry: The cause can arise as the result of failure, human error, design inadequacy, induced or natural environment, system configuration or operational mode(s).

Note 2 to entry: This definition is specific to this document, when used in the context of hazard analysis.

### 3.1.3

#### **caution condition**

condition which has the potential to degrade into a warning condition, and which might require specific action, including the implementation of special procedures or restrictions on the operation of the system

[SOURCE: EN 13701:2001]

### 3.1.4

#### **common cause failure**

failure of multiple items occurring from a single cause which is common to all of them

[SOURCE: Adapted from NUREG/CR-2300 PRA:1982]

### 3.1.5

#### **common mode failure**

failure of multiple identical items that fail in the same mode

Note 1 to entry: Common mode failures are a particular case of common cause failures.

[SOURCE: NUREG/CR-2300 PRA:1982]

### 3.1.6

#### **critical fault**

fault which is assessed as likely to result in injury to persons, significant material damage, or other unacceptable consequences

[SOURCE: IEC 60050:1992]

### 3.1.7

#### **emergency**

condition when potentially catastrophic or critical hazardous events have occurred, where immediate and pre-planned safing action is possible and is mandatory in order to protect personnel

[SOURCE: Adapted from EN 13701:2001]

### 3.1.8

#### **fail safe**

design property of an item which prevents its failures from resulting in critical faults

[SOURCE: IEC 60050:1992]

### 3.1.9

#### **failure**

termination of the ability of an item to perform a required function

[SOURCE: IEC 60050:1992]

### 3.1.10

#### **fault**, noun

<state> the state of an item characterized by inability to perform as required, excluding the inability during preventative maintenance or other planned actions, or due to lack of external resources

Note 1 to entry: A fault is often the result of a failure of the item itself, but can exist without prior failure.

[SOURCE: Adapted from IEC 60050:1992]

### 3.1.11

#### **fault**, noun

<event> an unplanned occurrence or defect in an item which may result in one or more failures of the item itself or of other associated equipment

Note 1 to entry: An item may contain a sub-element fault, which is a defect that can manifest itself only under certain circumstances. When those circumstances occur, the defect in the sub-element will cause the item to fail, resulting in an error. This error can propagate to other items causing them, in turn, to fail. After the failure occurs, the item as a whole is said to have a fault or to be in a faulty state ([3.1.10](#)).

[SOURCE: IEC 60050:1992, modified — Note 1 to entry from EN 13701:2001]

### 3.1.12

#### **hazard**

existing or potential condition of an item that can result in an accident

Note 1 to entry: This condition can be associated with the design, fabrication, operation or environment of the item, and has the potential for mishaps.

Note 2 to entry: “Items” can include human beings.

[SOURCE: ISO 14620-2:2011, 3.9, modified — “mishap” changed to “accident”, Note 2 to entry added]

### 3.1.13

#### **hazardous event**

occurrence leading to undesired consequences and arising from the triggering by one (or more) initiator events of one (or more) hazards

[SOURCE: Adapted from EN 13701:2001]

### 3.1.14

#### **inhibit**

design feature that provides a physical interruption between an energy source and a function actuator

EXAMPLE A relay or transistor between a battery and a pyrotechnic initiator, a latch valve between a propellant tank and thruster.

Note 1 to entry: Two inhibits are independent if no single failure can eliminate more than one inhibit.

[SOURCE: Adapted from EN 13701:2001]

### 3.1.15

#### **residual risk**

risk remaining in a system after completion of the hazard reduction and control process

[SOURCE: EN 13701:2001]

### 3.1.16

#### **safe state**

state that does not lead to critical or catastrophic consequences

**3.1.17****safety critical function**

function that, if lost or degraded, or as a result of incorrect or inadvertent operation, would result in catastrophic or critical consequences

[SOURCE: Adapted from EN 13701:2001]

**3.1.18****safing**

action of containment or control of emergency and warning situations or placing a system (or part thereof) in a predetermined safe condition

[SOURCE: EN 16601-00-01:2015, 2.3.180]

**3.1.19****system safety**

application of engineering and management principles, criteria, and techniques to optimize all aspects of safety within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle

**3.1.20****warning condition**

condition where potentially catastrophic or critical hazardous events are imminent and where pre-planned safing action is required within a limited time

[SOURCE: Adapted from EN 13701:2001]

**3.1.21****zonal analysis**

systematic inspection of the geographical locations of the components and interactions of a system, evaluation of potential subsystem-to-subsystem interactions with and without failure, and assessment of the severity of potential hazards inherent in the system installation

**3.2 Abbreviated terms**

The following abbreviated terms are used within this document.

|          |                                                    |
|----------|----------------------------------------------------|
| CCB      | Configuration Control Board                        |
| EEE      | Electronic, Electrical, Electromechanical          |
| FMECA    | Failure Modes, Effects And Criticality Analysis    |
| FTA      | Fault Free Analysis                                |
| GSE      | Ground Support Equipment                           |
| IAW      | In Accordance With                                 |
| IEC      | International Electrotechnical Commission          |
| MIP      | Mandatory Inspection Point                         |
| NRB      | Nonconformance Review Board                        |
| NUREG-CR | US Nuclear Regulatory Commission contractor report |
| TRB      | Test Review Board                                  |
| VTL      | Verification Tracking Log                          |

## 4 System safety programme

### 4.1 Scope

- a) The scope and content of the safety programme is to establish a safety management system to implement provisions of this document commensurate with the programme requirements.
- b) The system safety programme should be tailored by the customer in accordance with the type of project, safety criticality, complexity, and phase of development in accordance with the requirements of ISO 14300-1 and ISO 14300-2.
  - 1) The supplier shall establish and maintain a system safety programme.
  - 2) The supplier shall ensure that all applicable national or international safety regulations, including those for launch site safety, space debris mitigation and re-entry are identified.
  - 3) The appropriate system safety programme requirements of this document shall be applied.
- c) Tailoring shall not diminish the intent to protect flight and ground personnel, the launch vehicle, associated payloads, ground support equipment, the general public, public and private property, and the environment from hazards associated with space systems.

### 4.2 Safety organization

#### 4.2.1 General

Each supplier is responsible for the safety of his product as detailed in next sub clauses.

#### 4.2.2 Safety representative

Each supplier shall appoint a safety representative in accordance with ISO 14300-2 who is qualified by training or experience to perform system safety functions.

#### 4.2.3 Reporting lines

Safety representatives shall have reporting lines to the project manager and access to top management that are independent of the hierarchical reporting line within the project.

#### 4.2.4 Safety integration

Safety shall be integrated in all project activities.

#### 4.2.5 Coordination with others

The safety representatives shall coordinate with all relevant bodies such as safety launcher authority, affected medical boards, radiation protection committees, industrial safety organizations and environmental protection agencies.

### 4.3 Safety representative access and authority

#### 4.3.1 Access

The safety representative of an organization shall have access to that organization's safety related data relevant to project safety, and shall be at liberty to report freely, and without organizational constraint on any aspect of project safety.

#### 4.3.2 Delegated authority to reject — stop work

The safety representative of an organization shall have the delegated authority to reject any project document, or to stop any project activity of this organization that does not conform to approved safety requirements or procedures.

#### 4.3.3 Delegated authority to interrupt operations

To properly control risk, the safety representative of an organization shall have the delegated authority to interrupt hazardous operations of this organization and make the system under consideration safe again when it becomes clear that the operation does not conform to the agreed measures.

#### 4.3.4 Conformance

The supplier shall ensure conformance of his own and his sub-suppliers' project activities with project safety policy and requirements.

#### 4.3.5 Approval of reports

The supplier shall not permit project reports that address matters related to safety certification to be issued without signed approval of the safety representative.

#### 4.3.6 Review

No project hazardous operation or system mission shall be permitted to proceed without prior review and approval by the safety representative.

#### 4.3.7 Representation on boards

Safety should be represented at configuration control boards (CCBs), non-conformance review boards (NRBs), test review board (TRBs), and at qualification, and acceptance reviews, where safety requirements and safety critical functions are involved. Safety shall be further represented at medical boards or equivalent where exposure or endurance limits are defined for flight and ground crews.

### 4.4 Safety risk management

#### 4.4.1 Safety risks

Risk to human life, investments made, mission and environment shall be managed throughout the project by performing the following activities:

- a) allocation of safety requirements;
- b) hazard identification;
- c) hazard evaluation;
- d) hazard prevention, reduction, and control; and
- e) hazard close out, including residual risk acceptance.

#### 4.4.2 Hazard assessment

All hazard assessments shall consider primarily the hazard potential and categorize all hazards according to the appropriate severity category. Corresponding controls shall be proposed. The initial design shall be chosen such that the hazard potential and its related consequence severity are minimized. The probability of a hazardous event shall consequently be taken into account whenever hazard consequence severity reduction methods alone are considered insufficient to adequately reduce the risk. The probability of occurrence shall be reduced by considering all areas of design for minimum

risk, increasing the reliability of safety devices, providing warning devices, or using procedural controls and training.

#### 4.4.3 Preferred measures

Hazard potential reducing measures that as a minimum do not reduce reliability shall be preferred. Probability and therefore risk-related reduction measures that do not lead to increased criticality shall be preferred.

### 4.5 Project phases and safety review cycle

#### 4.5.1 Progress meetings

The supplier shall hold regular safety progress meetings to review the status of safety programme activities as required by this document. The meetings may be attended by the relevant customer and supplier specialists.

#### 4.5.2 Project reviews

##### 4.5.2.1 General

- a) The supplier shall support safety reviews organized by the customer and, as necessary, the safety approval authority of the project safety status as required.
- b) Safety reviews shall be performed at all levels necessary to ensure satisfactory implementation of safety programme and technical safety requirements.
- c) A safety data package shall be prepared for each review.
- d) Safety reviews should be performed in conjunction with the following milestones as applicable and the objectives as described in the respective sub clause.

##### 4.5.2.2 Mission definition review

During the mission definition review, the supplier shall demonstrate that:

- a) Safety requirements and lessons learned from previous projects were analysed and support was provided to design and operations concept trade-off; and
- b) Main system level safety requirements were identified.

##### 4.5.2.3 Preliminary requirements review

During the preliminary requirements review, the supplier shall demonstrate that:

- a) System level applicable hazards, hazardous conditions and events, together with safety critical aspects and safety risk of the concepts analysed, were identified and compared; and
- b) Project system level safety requirements were refined.

##### 4.5.2.4 System requirements review

During the system requirements review, the supplier shall demonstrate that:

- a) Safety requirements were specified in sufficient detail to allow the definition of the technical solutions for the system concept selected in phase A, the feasibility phase; and
- b) Results of the safety analysis were available in order to confirm that the recommended solution was in agreement with the project safety requirements.

#### 4.5.2.5 Preliminary design review

During the preliminary design reviews, the supplier shall demonstrate that:

- a) Hazard controls and safety requirements were sufficiently defined for detailed design to start;
- b) The design as presented conforms to the safety requirements to the level of detail required by the review;
- c) Verification methods for hazard controls were proposed;
- d) Definition of safety requirements was finalized at system and at lower levels;
- e) The required activities were included in the project verification programme; and
- f) Deviations from safety requirements were identified.

#### 4.5.2.6 Critical design review

During the critical design review the supplier shall demonstrate that:

- a) The results of the safety analyses, performed on the solution obtained in the previous phase, were made available in order to permit verification that the detailed design is in agreement with the project safety requirements and can be used as a basis for manufacturing models to be used for qualification;
- b) All changes made to technical requirements were assessed with respect to consequent changes to hazard controls;
- c) Safety verification methods for all hazard controls were agreed upon and the necessary activities were entered into the verification programme.

#### 4.5.2.7 Qualification review

During the qualification review, the supplier shall demonstrate that:

- a) All design qualification activities related to critical items and safety critical functions, as appropriate to the level of the review, were completed and the applicable reports were approved; and
- b) All safety critical functions were qualified.

#### 4.5.2.8 Acceptance review

During the acceptance review the supplier shall demonstrate that:

- a) All late changes introduced into the design and technical requirements were assessed with respect to consequential changes to hazard controls and their verifications;
- b) Verification for all defined hazard control measures was completed and accepted;
- c) All open verifications were recorded in the verification tracking log (VTL) at this time. Verification procedures for verifications open at time of acceptance were qualified and mutually agreed upon as appropriate for later execution; and
- d) All safety related non-conformances, failures, waivers, and accident or incident reports were formally accepted and closed or documented on an open-items list with any constraints identified.

#### 4.5.2.9 Flight readiness review

During the flight readiness review the supplier shall demonstrate that:

- a) The VTL shows no further open verifications;

- b) Verifications which shall be performed nominally at a later point in time (i.e. late access inspections), are closed on the basis of an existing, documented launch organization procedure and are executed by personnel who have been trained according to this procedure;
- c) All open work related to safety critical functions was completed or scheduled as part of normal pre-launch activities;
- d) All safety related non-conformances, failures, waivers, and accident or incident reports were formally accepted and closed; and
- e) All safety related flight anomalies on previously flown common designs or re-flown hardware were resolved and closed.

#### 4.5.2.10 Operational readiness review

During the operational readiness review, the results of the vehicle/ground compatibility tests and the operational qualification tests (during which the operational procedures shall have been verified) shall be assessed. This assessment shall verify that the combined operation of vehicle and ground facilities does not introduce new hazards or require additional controls.

#### 4.5.2.11 Launch commitment meeting

During the launch commitment meeting, the current safety status shall be presented which documents any potential effects of countdown anomalies, weather and hardware or personnel conditions. It shall state whether the safety status is acceptable for launch to proceed and shall be subject to review and formal acceptance by the customer and the safety approval authority.

#### 4.5.2.12 In orbit test review

During the in-orbit test review, the validity of previous hazard and risk acceptance shall be reconfirmed considering any design or operational changes which have been introduced. This shall include assessment of the continued validity of previously accepted operational margins, and waivers against safety critical functions. Updated safety analyses shall be provided as necessary to support the decision to authorize continuous usage of the system.

#### 4.5.2.13 End-of-life assessment

During the end-of-life assessment, a safety package shall be provided which documents the safety status of the system with respect to its capability to support the planned end-of-life and disposal operations and their conformance with the applicable requirements.

#### 4.5.3 Safety programme review

The safety programme shall be reviewed, depending on project criticality, either:

- a) as part of the scheduled project milestone reviews; or
- b) as part of a dedicated safety review.

#### 4.5.4 Safety data package

The supplier shall prepare and deliver the safety data package. The content of the safety data package shall be defined for each project or programme by the safety approval authority.

## 4.6 Safety programme plan

### 4.6.1 Implementation

The supplier shall show how the safety programme is implemented in the safety programme plan in accordance with ISO 14300-2. The plan may either be included as part of an overall project product assurance plan or as a separate safety programme sub-plan.

### 4.6.2 Safety activities

Safety planning shall cover the safety activities for the project phases as defined in ISO 14300-1. [GOAL] Safety planning should result in a set of activities that not only achieve all contractual system safety requirements, but are also commensurate with the system's unit-value/mission-criticality and life cycle technical data content/maturity. This type of planning is sometimes referred to as capability-based process tailoring. An example of space systems unit-value/mission-criticality category definitions and guidance for tailoring a capability-based system safety programme are provided in ISO/TS 18667.

### 4.6.3 Definition

The plan shall define:

- a) the safety programme tasks to be implemented;
- b) the personnel or supplier responsible for the execution of the tasks;
- c) the schedule of safety programme tasks related to project milestones;
- d) safety programme activity interface with project engineering and with other product assurance activities; and
- e) how the supplier accomplishes the tasks and verifies their satisfactory completion (by reference to internal procedures as appropriate).

### 4.6.4 Description

The plan shall include a description of the project safety organization, its responsibilities, and its working relationship with the reliability, maintainability, software product assurance, parts, materials and processes and quality assurance disciplines of product assurance, with configuration management, system engineering, design and other project functions and departments of organizations.

### 4.6.5 Safety and project engineering activities

The plan shall show how the project safety organization implements concurrent safety and project engineering activities in continuous support of the project design and development process.

### 4.6.6 Supplier and sub-supplier premises

The plan shall describe how safety related activities and requirements are defined for, and controlled at, suppliers' and sub-suppliers' premises. Only those requirements that are relevant to the sub-suppliers' and suppliers' activities and responsibilities shall be made applicable.

### 4.6.7 Conformance

The plan shall make provisions to ensure safety requirements and regulations applicable to any other facilities and service that are utilized during the course of the project are identified.

#### 4.7 Safety certification

- a) All projects shall certify the safety of the flight and ground system products as having reached an acceptable level of risk in conformance to project specific safety requirements.
- b) The certification process shall be completed before delivery to any party other than the purchaser.
- c) The certification shall include a statement that open verifications shall be closed in accordance with the established verification tracking log and do not affect further safe processing at third party premises.
- d) For any given project, the entity that defines, or makes applicable, detailed technical safety requirements constitutes the safety approval authority or part thereof.
- e) It shall be the responsibility of the project organization to provide to the certification authority all safety related information that is required to enable the statement of safety compliance to be accepted and understood.

#### 4.8 Safety training

##### 4.8.1 Overall training

- a) Safety training is a part of the overall training as required by ISO 14300-1 and ISO 14300-2.
- b) All safety related training of any personnel working - permanently or occasionally - with products that can have hazardous properties has three major aspects:
  - 1) general awareness briefings on safety measures to be taken at a given location or working environment;
  - 2) basic technical training in the required safety techniques and skills (e.g. inspection, test, maintenance or integration), which are mandatory to fulfil the job function under consideration; and
  - 3) product specific training that focuses on the hazards related to the specific product.

##### 4.8.2 Participation

Participation in the general awareness briefing shall be mandatory for all personnel who have access to the area where the product is processed.

##### 4.8.3 Detailed technical training

Detailed technical training shall be provided to all project engineering and safety personnel working with hazardous products.

##### 4.8.4 Product specific training

Product specific training shall be provided by specialists to all new project engineers as well as the flight and ground crews.

##### 4.8.5 Records

Records of personnel having received training shall be maintained.

##### 4.8.6 Identification

Where safety training is identified as required for the flight operations crew or for mission control personnel, this shall be identified to the customer together with a definition of the type of training

required and its scope. The supplier shall support implementation of the training programme as defined by the customer.

#### 4.9 Accident/incident reporting and investigation

- a) The supplier shall report to the responsible entity all accidents and incidents that affect the product and occur during project activities under the control of the supplier or his sub-suppliers.
- b) The supplier shall support project related accident and incident investigations that occur outside of the supplier's control or facility at the request of the responsible entity.

#### 4.10 Safety documentation

##### 4.10.1 General

The supplier shall maintain safety-related data to support reviews and safety certification.

##### 4.10.2 Customer access

The customer shall be given access to the data contained in the safety data file on request during audits, reviews and meetings held at the supplier's premises within the restrictions of the contract.

##### 4.10.3 Supplier review

The supplier shall review project documentation including specifications, drawings, analyses, procedures and reports, non-conformance reports, failure reports, waivers, and documentation changes in order to verify or assess impact on:

- a) the implementation of safety requirements and hazard and risk controls;
- b) incorporation of hazard and risk controls into the design or the verification programme;
- c) completion of verification activities;
- d) the design and operational safety of the system; and
- e) the validity of safety analyses performed and documented.

##### 4.10.4 Documentation

- a) Records shall be maintained of the documents reviewed.
- b) Safety documentation shall be updated where necessary to maintain currency.
- c) The supplier shall certify that the safety documentation is accurate, valid, comprehensive, and complete prior to launch site processing.

##### 4.10.5 Safety data package

- a) The supplier shall submit a safety data package for review; see [4.5.4](#). This may be a stand-alone package or may be integrated into the overall data package if the safety review is part of an overall project review.
- b) The content of the data package shall be specified by the safety approval authority.
- c) The design and operational baseline that is the subject of the safety data package shall be defined by reference to the relevant documentation.
- d) Any data requested during previous safety reviews shall be incorporated into the safety data package.

- e) The supplier shall integrate safety data related to the various subsystems or equipment that make up the system into the safety data package that is presented at the safety review.
- f) All safety data shall be traceable from the safety data package and available for review as appropriate.

#### **4.10.6 Safety deviations and waivers**

##### **4.10.6.1 Request for deviation**

Safety requirements that cannot be met shall be identified and a request for deviation or waiver shall be generated.

##### **4.10.6.2 Description, analysis and rationale**

The deviation or waiver request shall describe why the requirement cannot be met and provide sufficient analysis and rationale to support an exception to the safety requirement.

##### **4.10.6.3 Identification and review**

The supplier shall identify all deviations and waivers that affect the applicable project safety requirements. The supplier's safety representative for the project shall review these deviations and waivers to ensure that possible impacts on safety are fully analysed. Adequate justification for any deviation considered acceptable by the supplier shall be provided.

##### **4.10.6.4 Assessment of deviation**

The accumulated deviations and waivers that affect safety shall be assessed to ensure that the effects of individual deviations do not invalidate the rationale used for the acceptance of other deviations. The supplier shall maintain a tracking list that identifies all safety-related deviations and waivers reviewed.

##### **4.10.6.5 Review and disposition**

Deviations and waivers that affect project safety requirements or safety critical functions which the supplier considers acceptable, shall be the subject of review and disposition by the customer's safety authority.

##### **4.10.6.6 Certification authority approval**

Safety deviations and waivers shall be subject to safety approval authority acceptance.

##### **4.10.7 Verification tracking log**

A verification tracking log shall be maintained in which the completion steps associated with hazard control verification items are clearly stated. Once the verification methods have been documented to mutual satisfaction of project and certification bodies, the verification tracking log establishes the validation record.

##### **4.10.8 Lessons-learned file**

- a) The supplier shall collect the safety lessons learned during the project. The supplier shall make sure that the lessons learned are used during the project, as far as they are relevant.
- b) Safety lessons learned should consider as a minimum:
  - 1) the impact of newly imposed requirements;
  - 2) assessment of all malfunctions, accidents, anomalies, deviations and waivers;

- 3) effectiveness of safety strategies of the project;
- 4) new safety tools and methods which have been developed or demonstrated;
- 5) effective versus ineffective verifications which have been performed; and
- 6) changes proposed to safety policy, strategy or technical requirements with rationale.

## 5 Safety engineering

### 5.1 Safety engineering objectives

#### 5.1.1 General

Safety is an integral part of all project product assurance and engineering activities. The quality of all safety engineering related work shall be based on assurance that the system is designed, qualified, manufactured, and operated in accordance with product assurance requirements.

#### 5.1.2 Elements

Safety engineering consists of management of hazard and risk reduction processes, hazard and risk potential assessment, design assurance, and hazard and risk control activities.

#### 5.1.3 Lessons learned

Maximum use should be made of lessons learned in the design process.

### 5.2 Safety design principles

#### 5.2.1 Human life consideration

The preservation of personnel safety shall be the most important priority in the development and operation of space systems.

#### 5.2.2 Design selection

The major goal throughout the design phase shall be to ensure inherent safety through the selection of appropriate design features. Damage control, containment and isolation of potential hazards shall be included in the design considerations. The design shall allow for debris, fall-out and impact prevention.

#### 5.2.3 System safety order of precedence

The following sequence of activities shall be applied to identified hazards, hazardous conditions, and functions whose failures have hazardous consequences:

##### a) Hazard elimination

Hazards and hazardous conditions shall, consistent with the project constraints and mission objectives, be eliminated from the design and operational concepts by the selection of design technology, architecture and operational characteristics.

##### b) Hazard minimization

Where hazards and hazardous conditions are not eliminated, the severity of the associated hazardous events and consequences shall, consistent with the project constraints and mission objectives, be minimized through selection of the least hazardous design architecture, technologies, and operational characteristics.

c) Hazard control — Safety devices

Hazards that are not eliminated through design selection shall be reduced and made controllable through the use of automatic safety devices as part of the system, subsystem or equipment. Safety inhibits shall be independent and verifiable.

d) Hazard control — Warning devices

When it is not practical to preclude the existence or occurrence of known hazards or to use automatic safety devices, devices shall be employed for the timely detection of the condition and the generation of an appropriate warning signal. This shall be coupled with emergency controls of corrective action for operators to safe or shut down the affected subsystem.

e) Hazard control — Special procedures

- 1) When it is not possible to reduce the magnitude of a hazard through the design, the use of safety devices or the use of warning devices, special procedures shall be developed to counter the hazardous conditions for the enhancement of flight crew safety.
- 2) Special procedures can include emergency and contingency procedures, procedural constraints, or the application of a controlled maintenance programme.
- 3) Special procedures shall be qualified and appropriate training shall be provided for personnel.
- 4) Special procedures are the least effective of the hazard control and risk reduction measures available. Emphasis shall therefore be given to hazard control by the application of the alternative hazard control measures in the defined order of precedence.
- 5) The requirement for hazard detection, signalling and safing by the flight crew to control time-critical hazards shall be minimized and shall not be implemented if an alternative means of reduction or control of hazardous conditions is available.
- 6) To permit the use of real time monitoring, hazard detection and safing systems for hazard control, the availability of sufficient flight crew response time shall be verified. Acceptable safing procedures shall be developed and verified and the personnel trained.
- 7) Physical barriers, safe separation distances, minimal personnel allowance with access control, remote monitoring, tag out/lockout methods, and time-limited exposure shall be considered as means of hazard mitigation and risk reduction.

#### 5.2.4 Environmental compatibility

- a) The system design shall meet the applicable safety requirements under the worst-case natural and induced environments defined for the project.
- b) Design and performance margins shall be established and applied considering worst-case combinations of induced and natural environments and operating characteristics.

#### 5.2.5 Safe without services

Whenever the safe operation of the system depends on externally provided services (e.g. power), the system design shall be such that critical or catastrophic consequences are not induced (at least for a certain interval of time that shall be defined for each project) after the loss or upon the sudden restoration of those services.

#### 5.2.6 Fail safe design

The system, and its parts thereof, shall be designed in such a way that failures bring the system into a safe state.

### 5.2.7 Hazard detection — Signalling and safing

- a) Safety monitoring, display, alarm and safing capabilities shall be incorporated for human space flight systems.

These capabilities shall provide the information necessary to allow the flight crew and ground system operators to take actions which are necessary to protect personnel from the consequences of failures within safety critical functions and the failure of hazard control measures.

- b) The system design shall provide the capability for detecting failures that result in degradation of failure tolerance with respect to the hazard detection, signalling and safing function. When implemented, the performance of these functions shall be verifiable during manned flight and ground operational phases.
- c) The emergency, caution and warning function shall detect and notify the flight crew and ground system operators of emergency, warning and caution situations.
- d) Safing functions and capabilities shall be included which provide for the containment or control of emergency, warning and caution situations.
- e) Provisions shall be included for the monitoring of safing function execution.
- f) Dedicated safing functions shall be provided for emergency situations. Control of warning and caution situations shall be acceptable by system re-configuration or by dedicated safing functions, as appropriate to each case.
- g) No single failure shall cause loss of the emergency and warning function.
- h) Where the operation of a safing system introduces a new hazard, as a minimum, inadvertent activation of the safing system shall be controlled in accordance with the failure tolerance requirements.
- i) No single failure shall cause loss of the emergency and warning functions together with the monitored functions.
- j) Emergency, warning and caution data, out of limit annunciation and safing commands shall be given priority over other data processing and command functions.
- k) When systems or elements are integrated into, or docked with the other systems or elements, the emergency, warning, caution, and safing function shall enable the areas of control responsibility to monitor and display the applicable parameters, and to control the relevant safing functions.
- l) Emergency, warning, and caution parameter status information shall be available and displayed at the launch control and mission control centres in “near-real-time” during the relevant operational phases. It shall be possible for the flight crew to ascertain and monitor in “real time” the status of emergency, warning and caution parameters of non-crewed systems or elements prior to docking with crewed systems.

### 5.2.8 Access

All project products shall be designed such that any required access to products during flight or ground operations can be accomplished with minimum risk to personnel.

### 5.2.9 Safety risk reduction and control

- a) **Consequence severity assessment**

The severity of identified hazardous events shall be categorized as shown in [Table 1](#). For international programmes, a coherent set of consequence severity categories shall be established for joint operational phases. These categories shall not diminish the intent to protect human life,

nor the principles of categorization in accordance with the definition of consequence severity categories in [Table 1](#).

The availability of design features which reduce the probability of a hazardous event occurring but which do not affect its severity, or warning devices, or flight crew safe haven, or flight crew escape capabilities, shall not be used as rationale for the reduction of the hazard severity level.

The consequence severity impacts of flight system hazards on human life shall be assessed. This impact can be immediate and personal, it can be on a broader scale not limited to a single person, or it can be short term or long term. Detrimental environmental effects, from the point of view of long term hazardous consequences to the global public, shall be considered.

In the case of space flight safety, the consequence severity of space system hazards shall be assessed according to their impact on other active space systems and the space environment.

**Table 1 — Severity category definitions of identified hazards and consequences**

| Severity categories |                      | Type of consequence                                                                                          |                                                                                                                                                    |
|---------------------|----------------------|--------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| 1)                  | Catastrophic hazards | i)                                                                                                           | Loss of life, life-threatening or permanently disabling injury or occupational illness, loss of an element of an interfacing manned flight system; |
|                     |                      | ii)                                                                                                          | Loss of launch site facilities or loss of system;                                                                                                  |
|                     |                      | iii)                                                                                                         | Severe detrimental environmental effects;                                                                                                          |
| 2)                  | Critical hazards     | i)                                                                                                           | Temporarily disabling but not life-threatening injury, or temporary occupational illness;                                                          |
|                     |                      | ii)                                                                                                          | Major damage to flight systems or loss or major damage to ground facilities;                                                                       |
|                     |                      | iii)                                                                                                         | Major damage to public or private property;                                                                                                        |
|                     |                      | iv)                                                                                                          | Major detrimental environmental effects.                                                                                                           |
| 3)                  | Marginal hazards     | Minor injury, minor disability, minor occupational illness, or minor system or environmental damage.         |                                                                                                                                                    |
| 4)                  | Negligible hazards   | Less than minor injury, disability, occupational illness, or less than minor system or environmental damage. |                                                                                                                                                    |

## b) Hazard risk assessment

### 1) General

As part of the risk management process implemented on the project (in accordance with ISO 17666), the contractor shall analyse, eliminate or control all unacceptable hazardous risks that may lead to the non-conformance of system safety requirements, i.e. all risks of degradation or loss of safety-critical functions required for the space system, and all risks of harm the space system poses to other operational space assets, the space environment, or public health when employed in an operational environment. Unacceptable hazardous risk reduction shall include the following steps:

- i) identification and classification of unacceptable hazardous conditions according to the severity classification of their consequences (see [Table 1](#)), through the assessment of safety-critical functions, failure modes, and scenarios, and their associated root causes or hazards;
- ii) identification of proposed actions and recommendations for unacceptable hazardous risks to be reduced to an acceptable level;
- iii) verification of elimination or control of unacceptable hazardous risks to an acceptable level;
- iv) decisions on residual hazard risk acceptance;
- v) tracking of residual hazard risk

### 2) Identification and classification of unacceptable hazardous conditions

The contractor shall identify unacceptable hazardous conditions that may lead to the loss or degradation of safety-critical items and functions, together with their classification into categories related to the severity of their consequences. Preliminary identification and classification of unacceptable events shall be determined from hazard analyses performed during the space system/equipment conceptual and preliminary design phases, or as required by the contract. Unacceptable hazardous conditions, whose occurrence can jeopardize, compromise, or degrade the success of safety-critical items and functions, shall be identified at all system levels (i.e. from the highest system level to the lowest parts level in all space and ground support systems). Identification and classification of all unacceptable hazardous conditions shall be documented IAW this document and the contract.

3) Identification of proposed actions and recommendations for unacceptable hazardous risk reduction

The contractor shall propose actions and recommendations for reducing unacceptable hazardous risks to an acceptable level. The appropriate best technical best practices shall be applied to estimate either the quantitative or qualitative probability of occurrence of each unacceptable hazardous condition and assess its risk. Through changes made to design or operations specifications, unacceptable hazardous risks shall be either eliminated or have their probability of occurrence reduced to an acceptable level.

4) Verification of elimination or control of unacceptable hazardous risks

The contractor shall perform appropriate verifications in order to ensure that identified unacceptable hazardous risks have been eliminated or reduced to an acceptable level.

The verifications methods used shall include the following, as appropriate:

- i) analysis;
- ii) testing;
- iii) demonstration;
- iv) inspection;
- v) similarity;
- vi) simulation.

Verification results shall be reported to project risk management for acceptance or complementary decisions.

5) Decisions on residual hazard risk acceptance

The contractor shall make and document decisions on residual hazard risk acceptance and actions for hazard risk reduction. Decisions shall be based on established criteria defined within the project risk policy, considering technical and programming implications. Decisions shall be document, controlled, and implemented within the risk management process applied to the project.

6) Tracking of residual hazard risk

The contractor shall track residual hazard risks throughout the space system/equipment life cycle.

### 5.3 Failure tolerance requirements

#### 5.3.1 Basic requirements

Failure tolerance is one of the basic safety requirements that is used to control hazards. The design of the system shall meet the following failure tolerance requirements:

- a) No single failure or operator error shall have critical (or catastrophic) consequences.

- b) No combination of:
  - 1) two failures, or
  - 2) two operator errors, or
  - 3) one failure and one operator error shall have catastrophic consequences.
- c) All hazards not controlled by conformance to failure tolerance shall be controlled by conformance to design to minimum risk or by meeting probabilistic safety targets.
- d) Technical requirements for areas of design for minimum risk shall be identified and approved by the relevant safety approval authorities.

### **5.3.2 Software**

- a) The required failure tolerance for software that supports a safety critical function shall be implemented utilizing dissimilar methods and algorithms (diversity). Alternatively, independent hardware back-up to the software function may be provided.
- b) Anomaly detection for, and actuation of safety functions, such as emergency stops, should be independent of software and program logic controllers.
- c) Acceptable software safety can be achieved through a formal software safety programme consisting of software hazard analysis, software design requirements analysis, test, and verification and validation.

### **5.3.3 Payload interface**

Having taken into account any failure tolerance of the payload services provided by the carrier, the payload shall be designed so that loss or degradation of resources, supplied to the payload by the carrier, shall not result in catastrophic or critical hazardous consequences.

### **5.3.4 Redundancy separation**

- a) The system design should include the capability for on-board redundancy management of safety critical functions, and provide failure tolerance and redundancy status information to the flight and ground crews, including immediate flight crew notification in the case of failure detection, redundancy switch-over, or loss of operational redundancy.
- b) Redundancy management shall include failure detection, failure isolation and switching of redundant items.
- c) The flight crew and mission control shall be able to override automatic safing and redundancy switch-over.
- d) Alternate or redundant safety critical functions shall be physically and functionally separated or protected in such a way that any event which causes the loss of one path shall not result in the loss of alternative, or redundant paths.

### **5.3.5 Failure propagation**

Hardware or software failures shall not cause additional failures with hazardous effects or propagate to cause the hazardous operation of interfacing hardware.

### 5.3.6 Design for minimum risk

#### 5.3.6.1 General

Hazards related to design for minimum risk areas of design (e.g. mechanisms, structures, pressure vessels, pressurized lines and fittings, pyrotechnic devices, material compatibility and material flammability) shall be controlled by the safety-related properties and characteristics of the design, such as margin or factors of safety. Failure tolerance requirements shall only be applied to the design process as necessary to ensure that credible failures that can affect the design do not invalidate safety-related properties.

#### 5.3.6.2 Fracture control

Where structural failure can have catastrophic or critical consequences, structures, pressure vessels, fasteners and load-bearing paths within mechanisms shall be designed in accordance with recognized fracture control standards.

#### 5.3.6.3 Safety factors

- a) Structural safety factors shall be defined and applied.
- b) The worst credible combination of environmental conditions shall be considered for determined safety margins.

#### 5.3.6.4 Materials

Materials shall be selected and controlled. Material selection shall ensure that hazards associated with material characteristics (e.g. toxicity, flammability, resistance to stress corrosion, outgassing, offgassing, resistance to radiation, resistance to thermal cycling, arc tracking, thermal degradation and microbiological growth) are either eliminated or controlled. If this is not feasible, the system design shall include the necessary provisions (e.g. containment of hazardous substances) to control hazardous events associated with material characteristics in accordance with the requirements of this document.

### 5.3.7 Probabilistic safety targets

- a) Probabilistic safety targets should be established for hazardous consequences at system level for each project or programme. These probabilistic targets should assist in the acceptable risk decision for each identified hazard.
- b) In establishing these safety targets, a procedure should be put in place to identify applicable requirements specified by launch safety authorities and national and international safety regulations. Additionally, the following criteria should also be taken into account when setting up the targets:
  - 1) with respect to targets for the ground and flight personnel, the individual risk should be comparable to the one accepted for other professionally exposed personnel (e.g. risk for flight crew members could be compared to the one for test pilots, risk for ground personnel should be comparable to the one for similarly exposed industrial workers);
  - 2) with respect to targets for the civil population, the total risk for the exposed ground population should be compared with the one caused by other hazardous human activities (e.g. risk from overflight of commercial aircraft, chemical plants, as appropriate).
- c) The assessment of conformance with the safety targets should also be used to:
  - 1) identify and rank major risk contributors;

- 2) support the decision-making process for those cases where non-conformances with the qualitative requirements are identified.
- d) Safety targets shall not be used as the sole requirements imposed on a system, but they should be used in combination with the other qualitative requirements of this document.
- e) Additionally, note that the allocation of “targets” to the various functions and subsystems is addressed in [6.1](#).

The conformance with the quantitative requirements shall be performed through risk analysis (see [6.4.3](#)).

## 5.4 Identification and control of safety critical functions

### 5.4.1 Identification

A system function that, if lost or degraded, or through incorrect or inadvertent operation, would result in a catastrophic or critical hazardous consequence, shall be identified as safety critical function.

EXAMPLE A series of operational events that can result in a hazard if they occur inadvertently or are operated out of order.

### 5.4.2 Inadvertent operation

Inadvertent operation of a safety critical function shall be prevented by:

- a) two independent inhibits, if it induces critical consequences; and
- b) three independent inhibits, if it induces catastrophic consequences.

### 5.4.3 Provisions

The system shall provide the following for manned space systems and the following should be a goal for ground operation of the system for unmanned space systems:

- a) failure tolerance and redundancy status information of safety critical functions;
- b) the status of at least two inhibits for manned flight and one inhibit for unmanned flight on functions that, if inadvertently operated, could lead to catastrophic consequences to the flight and ground crew, including:
  - 1) notification in real time in case of failure detection;
  - 2) announcement of any loss of operational redundancy;
  - 3) notification of redundancy switch-over; or
  - 4) changes of inhibit status.

### 5.4.4 Shutdown and failure tolerance requirements

The design shall either provide the capability for the safe shutdown of safety critical functions prior to in-flight maintenance operations or shall conform to the failure tolerance requirements during maintenance operations.

### 5.4.5 Electronic, electrical, electromechanical

Electronic, electrical, electromechanical (EEE) components used to support safety critical functions in flight standard hardware shall be selected and procured in accordance with the applicable programme requirements. See also ISO 14621.

## 6 Safety analysis requirements and techniques

### 6.1 General

- a) Safety analyses shall be performed in a systematic manner in order to ensure that sources of safety risk are identified and eliminated or are minimized and controlled.
- b) Safety risks can be the result of the hazardous characteristics associated with the:
  - 1) design, including the technology selected, the physical arrangement of elements, subsystems and equipment;
  - 2) operating modes;
  - 3) potential for operator error;
  - 4) operating environment; and
  - 5) hazardous effects which can result from the failure of functions.
- c) Safety analyses shall be initiated early in the design phase and shall provide concurrent support to project engineering in the selection of the least hazardous design and operational options that are compatible with the project mission and programme constraints.
- d) The results of safety analyses shall also be used to support project management in the verification of risk reduction, ranking of risk sources, support to project resource allocation, monitoring of risk trends, and residual risk acceptance.
- e) Analysis shall always be made with reference to a defined configuration baseline.

### 6.2 Assessment and allocation of requirements

#### 6.2.1 Safety requirements

The supplier shall respond to the applicable safety requirements for the project.

#### 6.2.2 Additional safety requirements

The supplier shall also identify additional safety requirements through the use of lessons learned from previous projects and the safety analyses performed during the project.

#### 6.2.3 Define safety requirements — functions

The supplier, taking into account the results of functional failure analysis and the system level safety requirements, shall define the safety requirements for the various functions of the system.

#### 6.2.4 Define safety requirements — subsystems

Subsequently the supplier, taking into account the results of the preliminary safety analysis and the architecture of the system, shall define the safety requirements associated with the various subsystems.

#### 6.2.5 Justification

The supplier shall justify the proposed allocation of safety requirements at the latest at the end of the detailed definition phase.

### 6.2.6 Functional and subsystem specification

The supplier shall ensure that the function and subsystem-level safety requirements are included in the relevant functional and subsystem specification.

## 6.3 Safety analysis

### 6.3.1 General

Safety analysis shall be refined and updated in an iterative manner as the design process proceeds, to ensure that hazards and hazardous events are assessed, and that the relevant detailed design and operational requirements, hazard controls, and verification activities are defined and implemented.

### 6.3.2 Mission analysis

Safety analysis shall support the identification of major sources of safety risk as well as the performance of preliminary trade-offs between possible system concepts.

### 6.3.3 Feasibility

Safety analysis shall support trade-offs in arriving at the concept that has acceptable safety risk considering the project and mission constraints. The design technology selected and the operational concept to be implemented shall be selected based on the analysis data for the safest system architecture to eliminate or minimize hazards.

### 6.3.4 Preliminary definition

The safety analysis shall support a continued and more detailed safety optimization of the system design and operations and the identification of technical safety requirements and their applicability. The analysis shall also provide inputs to safety risk assessment in support of safety risk evaluation, the identification of significant risk contributors in the design and in the operational concept.

### 6.3.5 Detailed definition, production and qualification

Safety analysis shall support detailed design and operational safety optimization, safety requirements implementation evaluation, risk reduction verification, and hazard and risk acceptance. Analysis of operations shall also support the identification of emergency and contingency response planning and training requirements, and the development of procedures.

### 6.3.6 Utilization

Safety analysis shall evaluate design and operational changes for impact on safety, verifying that safety margins are maintained and that operations are conducted within acceptable risk. The analysis shall also support the evaluation of operational anomalies for impact to safety, and the continued evaluation of risk trends.

### 6.3.7 Disposal

Safety analysis shall evaluate all disposal operations and the hazards posed to the ground population and environment by the disposal. Disposal solutions with minimal hazardous consequences shall be identified.

## 6.4 Specific safety analysis

### 6.4.1 General

The types of analyses to be selected for a given project shall be proposed by the product supplier on the bases of past experience and updated as necessary in the course of the safety analysis

NOTE Safety analysis consists of a combination of all the analyses described in the following sub-clauses. Supporting analysis is described in [6.5](#).

### 6.4.2 Hazard analysis

- a) Hazard analysis shall be performed in a systematic manner, beginning in the concept phase and continuing through the operational phase, including end-of-life and disposal.
- b) Hazard analysis shall identify and evaluate:
  - 1) hazards associated with system design, its operation and the operation environment;
  - 2) the hazardous effects resulting from the physical and functional propagation of initiator events;
  - 3) the hazardous events resulting from the failure of system functions and functional components; and
  - 4) time critical situations.
- c) The following potential initiator events shall be considered:
  - 1) hardware failure (random or time dependent);
  - 2) latent software error;
  - 3) operator error;
  - 4) design inadequacies, including:
    - i) inadequate margins;
    - ii) unintended operating modes caused by sneak-circuits;
    - iii) material inadequacies and incompatibilities;
    - iv) hardware — software interactions;
  - 5) natural and induced environmental effects; and
  - 6) procedural deficiencies.
- d) This includes a systematic analysis of the “system” operations and operating procedures which shall be performed in the detailed design and operational stages of a project. This analysis evaluates the capability of the system to be operated safely, to determine the safest operating modes, and to evaluate the acceptability of the operating procedures. The analysis shall be repeated as the design and operational detail evolves, particular attention being paid to the system’s operational modes and man/machine interfaces.

### 6.4.3 Safety risk assessment

- a) Safety risk assessment shall be performed in progressive steps during the implementation of the safety programme.
- b) Risk assessment shall be used to:
  - 1) support design trades (risk comparison);

- 2) rank risk contributors;
  - 3) identify major risk contributors;
  - 4) support the safety decision-making process (e.g. for waivers, unresolved residual risks);
  - 5) monitor the effectivity of the hazard control and risk-reducing process by assessing safety risk trends; and
  - 6) assess conformance to probabilistic safety targets.
- c) The results of safety risk assessment shall not be used as the sole basis for acceptance or rejection of residual risks.
- d) The supplier shall identify sources of data and rational used for safety risk assessment.

#### **6.4.4 Safety analysis for hardware-software systems**

##### **6.4.4.1 Safety critical function**

Software that implements or controls safety critical functions shall be subject to safety analysis. The software safety analysis may be performed as a stand-alone software safety analysis or as part of other safety analyses depending on the application. In any case, the scope and level of depth of the software safety analysis identified by means of the functional failure analysis and the preliminary system level safety analyses and its performance shall be coordinated with system FTA, hazard analysis, FMECA and sneak analysis, as appropriate.

##### **6.4.4.2 Requirements definition phase**

During the software requirements definition phase the supplier shall examine the system and the software requirements in order to identify unsafe modes (e.g. out of sequence, wrong event, inadvertent command, failure to command and deadlocking). The analysis should preferably be performed by means of (top level) FMECA and FTA. Appropriate software safety requirements shall be identified in the software requirements document to control the above mentioned unsafe modes.

##### **6.4.4.3 Architectural and detailed design phase**

During the software architectural design and the detailed design phases, the supplier shall determine where, and under what conditions, the system might trigger hazardous events. Input/output, timing and effects of hardware failures on the software should be included in the analysis at this stage. FTA and check list based design review methods may be used.

##### **6.4.4.4 Software code**

When the software code becomes available, the supplier shall:

- a) analyse for correctness and completeness;
- b) verify that the software safety requirements have been properly implemented; and
- c) verify that the software can handle the appropriate conditions with expected input overload conditions.

##### **6.4.4.5 Space debris mitigation**

For space debris mitigation requirements, ISO 24113 shall be applied.

## 6.5 Supporting assessment and analysis

### 6.5.1 General

The application of the following supporting assessment and analysis tools is at the discretion of the programme or project authorities.

### 6.5.2 Warning time analysis

- a) Warning time analysis shall be performed during the concept definition phase and the design and development phase in order to evaluate time-critical situations identified in the hazard analysis and to support the implementation of hazardous-situation detection and warning devices or contingency procedures.
- b) The analysis shall determine:
  - 1) the time during which the event shall be detected and the response action taken;
  - 2) the detection capability of the proposed design with respect to detection sensitivity and detection time;
  - 3) the resultant time available for response; and
  - 4) the adequacy of the proposed design or contingency procedures, including emergency evacuation, rescue, system re-configuration, redundancy switching, and maintenance.
- c) The detection times to be determined shall be:
  - 1) from the occurrence of the initiating event to the time when a hazardous consequence occurs (propagation time);
  - 2) the time from the occurrence of the initiating event to the time of earliest detection or annunciation; and
  - 3) the time taken for corrective action to be implemented.

### 6.5.3 Caution and warning analysis

- a) Caution and warning analysis shall be performed during the concept definition phase and the design and development phase of human space flight programmes in order to identify:
  - 1) emergency, warning, and caution parameters;
  - 2) the required safing functions and capabilities;
  - 3) limit sensing requirements; and
  - 4) the applicability of the individual "caution and warning" functions to the different mission phases.
- b) The caution and warning analysis shall utilize the results of the warning time and hazards analyses as appropriate.

### 6.5.4 Common cause and common mode failure analysis

#### 6.5.4.1 Multiple failures

Multiple failures, which result from common cause or common mode failure mechanisms, shall be considered as single failures for determining failure tolerance.

#### 6.5.4.2 Identification of requirements and scope

The supplier shall identify the requirement for and the scope of dedicated common cause and common mode analyses by means of the review of the results of the other safety analyses, such as fault tree analysis (FTA) and hazard analysis, and of the characteristic of the system and of its environment.

#### 6.5.4.3 Identification of common cause failures

The supplier shall identify potential common cause failures by assessment of the effects of common causes (e.g. radiation, thermal environment and fires). This analysis shall be performed in coordination with the FTA and the hazard analysis. The analysis of common cause failures can require that use be made of the result of dedicated engineering analyses (e.g. thermal analyses, meteorite or debris impact analysis).

#### 6.5.4.4 Analysis of common mode failures

Common mode failures shall be analysed by means of the use of check lists (to be established by the supplier) that list potential common modes for system components during the manufacturing, integration, test, operation and maintenance phases. The common mode analysis should be coordinated with the failure modes, effects and criticality analysis (FMECA).

#### 6.5.4.5 Integration of results

Results of common cause and common mode analysis should be integrated, at the appropriate level, together with the results of the system level safety analyses (fault tree analysis, hazard analysis).

#### 6.5.5 Fault tree analysis

The fault tree analysis shall be used to establish the systematic link between the system-level hazard and the contributing hazardous events and subsystem, equipment or piece part failure. A fault tree analysis, or its equivalent, shall be performed to verify the failure tolerance of the product.

#### 6.5.6 Human dependability analysis

- a) Whenever safety analyses identify human errors as a cause of catastrophic or critical hazards, a dedicated human dependability analysis should be carried out.
- b) The human dependability analysis shall be used to support the safety analysis for the identification of human operator error modes and their effects and for the definition of adequate countermeasures to prevent or control human errors.
- c) The human dependability analysis shall be developed from the early phases of the project onwards in order to define recommendations for the hardware and software design, procedure development and training preparation programme.

#### 6.5.7 Failure modes, effects and criticality analysis

The results of failure modes, effects and criticality analysis (FMECA) shall be used to support the hazard analysis in the evaluation of the effects of failures. FMECA and hazard analysis shall be considered complementary analyses.

#### 6.5.8 Sneak analysis

##### 6.5.8.1 Applicability

The aim of sneak analysis is to identify “sneak circuits”, i.e. unexplained paths for a flow of mass, energy, data or logical sequence that under certain conditions can initiate an undesired function or inhibit a desired function. Sneak circuits are not the result of failure but are latent conditions inadvertently