Programmatic Risk Management in Space Projects

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The focus of this article is the non-insurable programmatic risk at programme/project level. To stimulate risk awareness and to assist in risk mitigation and control, the Directorate of Manned Spaceflight and Microgravity has devised a process and established an implementation plan that is being applied to its major programmes.

Introduction

ESA's core business is the conception and the implementation of space programmes. A major element of this responsibility is the definition of requirements for and the development of space vehicles and instruments that support space research and applications. ESA performs this task in cooperation with its European industrial partners with whom the Agency agrees contracts on the basis of commercial proposals defining the technical tasks to be undertaken, the duration within which the tasks are to be completed, and the financial arrangements by which the Agency compensates its industrial partners for their efforts. Any programme undertaken by the Agency is limited in funding to the allocations provided by Member States and typically 80 to 85% of the allocated funds are passed to the participating companies.

ESA's space programmes vary significantly in size, duration, and complexity. They can range from some tens of millions of Euros to several thousand million Euros, and may be completed in just a few years or may last ten years or more. As far as complexity is concerned, a space programme may be conceived against a single objective with a well-defined end product, or with a multitude of objectives and a variety of products and services to be supplied.

All programmes embarked upon involve risks, risks that:
- the technology needed cannot be provided
- technical specifications are not met
- interfaces do not match
- required performance is not achieved
- products are not available in time
- costs are higher than estimated.

These and other risks need to be accounted for. ECSS-M-00-03A is an available standard (from ESA Publications Division) which may be consulted for establishing a suitable risk-management process.

At the outset, when a programme is initiated, risks may be covered through the allocation of a funding reserve as part of the financial envelope provided. However, in today's economic climate, the trend is to reduce such reserves to the absolute minimum at which a programme is still considered feasible. This leads to the question of how existing risks can be 'measured' and the results translated into a required allocation of a minimum funding reserve to cover them.

It is standard ESA practice for its space-vehicle development contracts with industry to include provisions for as many of the foreseeable risks as possible. These are generally in the technical domain. As this practice is constrained by how much risk the industrial partners are willing to bear for the funds offered, a considerable part of the total risk cannot be covered by this method. This share of the risk catalogue needs to be controlled by the Agency by the application of mitigation measures and through the retention of a funding reserve suitably sized to cover the remaining risk items.

Risk control requires awareness of the risk domains summarised in Figure 1.

The programmatic risk-management cycle

Programmatic risk management in ESA Programmes is an iterative process throughout the project life cycle, with iterations being determined by the progress through different project phases and by changes to a given baseline influencing resource allocations. Since the greatest uncertainty is in the earliest stages of a project, when decisions with major impacts are also made, risk analysis should be initiated as early as possible.

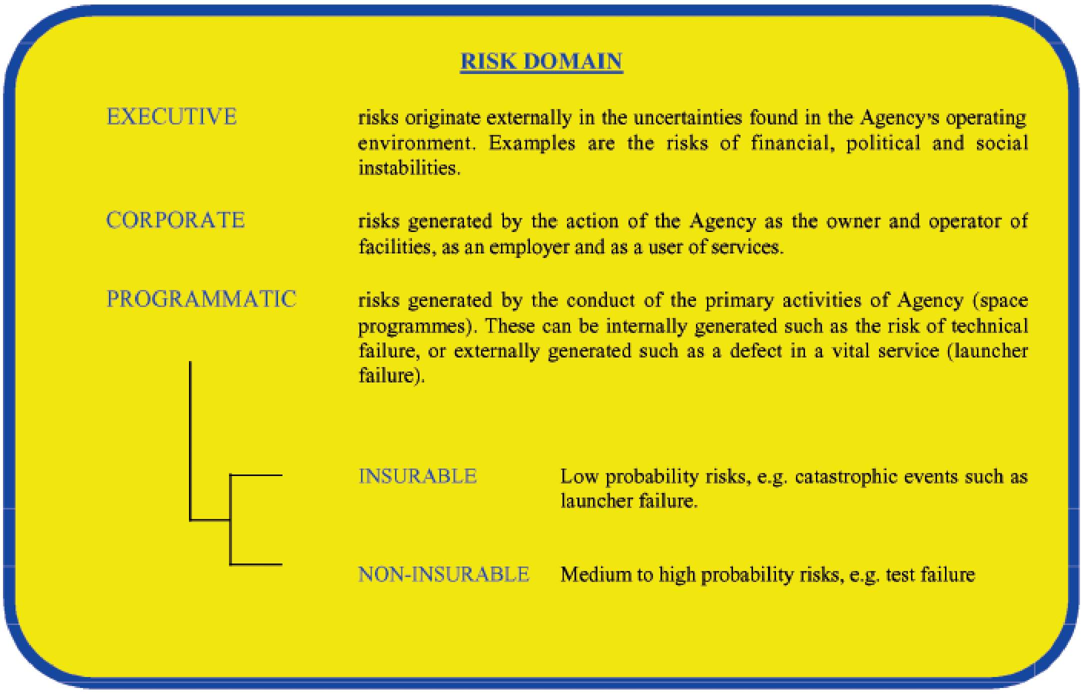

Figure 1. The risk domain

The process as applied in Manned Space and Microgravity is illustrated in Figure 2. The first step, the risk assessment, based on expert judgement, identifies and estimates the magnitude of the risk scenarios in terms of cost/schedule impact on the project baseline. In this phase, a risk-scenario prioritisation, based on a defined risk policy, is also carried out with the aim of sorting the risk scenarios in terms of their relative criticality. The second step addresses the contingency analysis and defines which risks may be accepted, and for which risk scenarios avoidance/mitigation plans must be prepared. The third step consists of the management and decision making by which avoidance/mitigation plans are implemented and the eventual acceptance of residual risk is approved. The fourth step, monitoring and reporting, foresees the systematic control and tracking of the implementation of the plans selected in the previous step. A report is produced to show the overall risk status of the project and to track the risk trend during its life cycle.

The frequency of application of the risk-management cycle depends on the needs and complexity of the programme/project. Occasional updates are required when major changes to the schedule, technologies, techniques, performance, etc. of the project baseline occur.

The identification of risk

Managing risk first of all requires that the risks be known. The risk analysis starts by gathering the project team and explaining the objectives of risk management. Under the supervision of

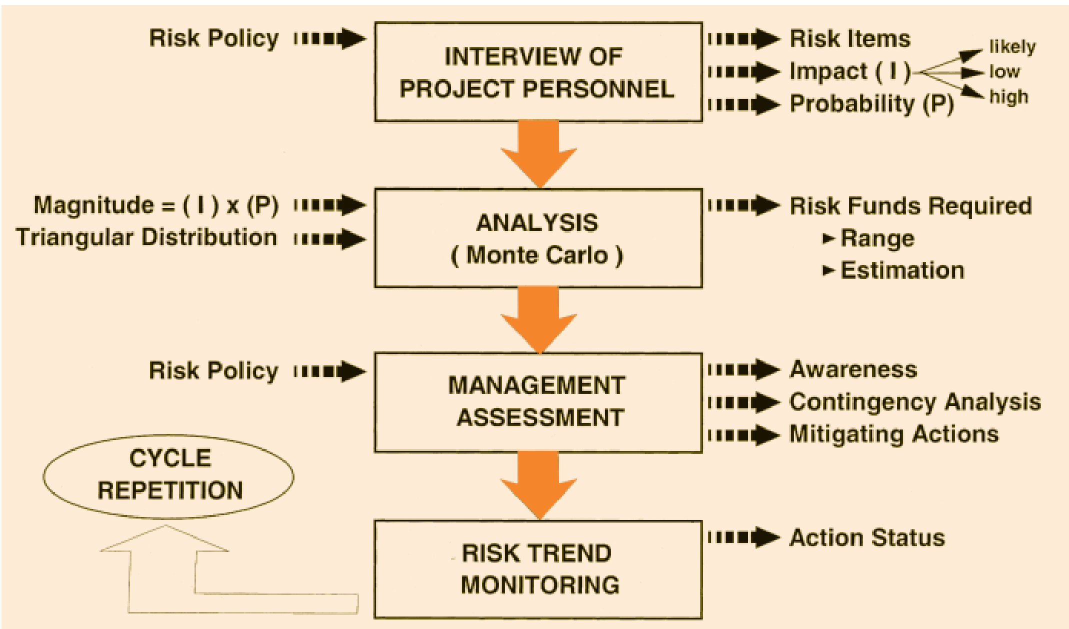

Figure 2. Process adopted in ESA's Manned Spaceflight and Microgravity Directorate

the Project Manager, who remains firmly in control at every stage of the process, 'experts' are selected to assist in the identification of risk scenarios.

Who are these experts? Typically they are knowledgeable individuals working either within the project team or supporting it from the outside. The latter group is useful in order to compensate possible biases and to contribute independent views and opinions. The number of experts may vary from 3-4 for small projects, to 10-15 for large ones. It is commonly acknowledged that, of all of the steps, risk identification has the greatest impact on the effectiveness of risk management. Accomplishing this step successfully certainly requires the acquisition of expert judgements. The way in which these judgements are collected is central to the value and effectiveness of the whole process.

Figure 3. Items to consider when performing a risk assessment

THE FOLLOWING IS A LIST OF ITEMS TO CONSIDER WHEN PERFORMING A RISK ASSESSMENT
ASSESS EACH CATEGORY AND ADD ANY CLARIFICATION AS NEEDED
SYSTEMS ENGINEERING AND INTEGRATION
· Design Maturity :
- Design definition and specs. reasonably mature (Min. Spec. TBD's)
- Design definition and specs. inadequate (numerous spec. TBD's)
· Program internal interfaces (maturity of definition and how handled with subcontractors)
· Program external interfaces (maturity of definition, approach to resolution of TBD's)
· Level of definition and timeliness of required systems integration data
· Complexity of systems analytical integration (highly interactive)
· Required analytical tools complexity :
- complex modelling tools required
- tools exist
- tools require development

This collection task is usually performed via a structured interview covering the widest programmatic risk domain, including:
- technical risks
- political risks
- contract condition risks
- financial risks
- contractor/sub-contractor and supplier risks
- human-resource risks
- schedule risks, etc.

The proven methodology applied – the Delphi method – foresees a set of structured questions, which are posed to each individual during the interview. A generic check list has been prepared drawing on past experience available at the Agency and in space industry (Fig. 3). The questions posed are open-ended in order to explore all facets of the risk scenarios. The interviewer, however, tries to obtain replies which identify the specific problem with the best detail possible and attempts to determine the probability of occurrence and the performance, cost and schedule impacts if the risk occurs. The answers are recorded in a Programmatic Risk Assessment Register (Fig. 4). During the interview, ways of preventing risks (or exploiting opportunities to do so) are also addressed and recorded.

In a subsequent step, the results of all of the interviews are consolidated, thus eliminating duplication and mediating between the different views expressed. The result of this exercise is submitted to the Project Manager and his team to obtain their concurrence for the data gathered to be used as input to the final Programmatic Risk Management Register.

Risk analysis

The risk analysis involves evaluation of the identified risk scenarios with the objective of determining their likelihood of occurrence and impact on such aspects as cost and schedule,

PROJECT: PROGRAMMATIC RISK ASSESSMENT REGISTER DATE:

RISK SCENARIOS			RISK	COST CONSEQUENCE (KEUR)			SCHEDULE CONSEQUENCE (MONTHS)			RISK MAGNITUDE		Timeframe of expected occurrence			
Risk type	Code	ITEM	LIKELIHOOD %	Likely	Lowest	Highest	Likely	Lowest	Highest	Expected Cost	Expected Delay	Start	End	RISK OWNER	COMMENTS
Industrial															
External															
Internal															
Commissioning															
SUM of RISK MAGNITUDE:															

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Figure 4. The Programmatic Risk Assessment Register

and identifying possible magnitudes. From the data collected in the Programmatic Risk Assessment Register, the risk magnitude can be expressed in terms of the equation in Figure 5.

$$R(n) = P(n) * I(n)$$

Where $P(n)$ = probability of occurrence of scenario **n**

$I(n)$ = likely cost/schedule impact of scenario **n**

Figure 5. The risk equation

The various risk scenarios are then cumulated to assess the total programme/project risk magnitude. The risk owner is the entity totally/partially responsible for bearing the risk consequences (e.g. ESA, Prime Contractor or both). Plotting the risk scenarios on a Probability-Impact Grid (Fig. 6) provides an immediate and intuitive means of representing the criticality of each risk scenario. It also facilitates risk prioritisation by indicating those areas on which attention should be concentrated.

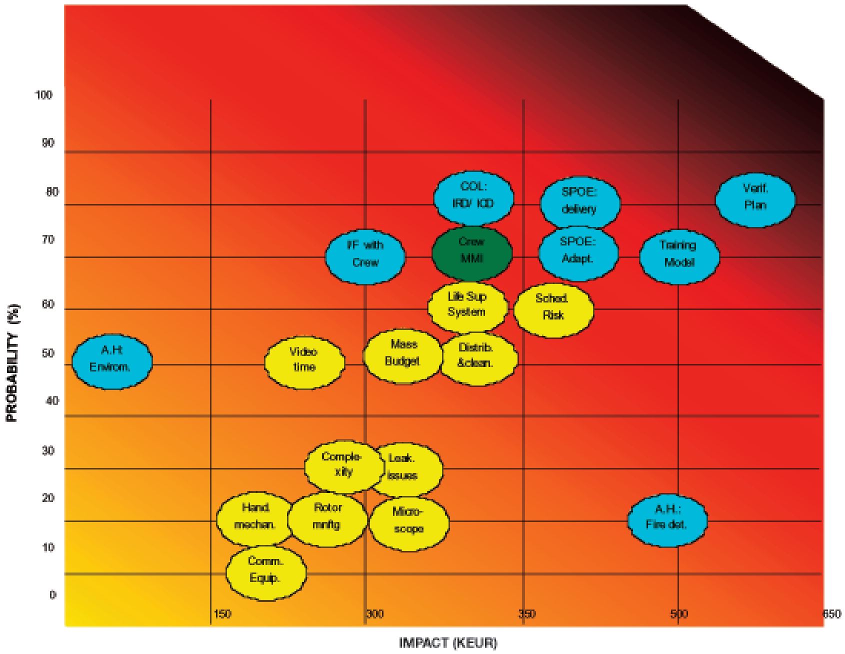

Figure 6. The Probability – Impact Grid

Such prioritisation alone, however, is not sufficient and needs to be complemented by a judgement based on a wider set of constraints, since risks of small magnitude may also be unacceptable under certain conditions. This set of constraints is referred to as the Risk Policy. Screening of the risk scenarios against the Risk Policy leads to the final prioritisation.

The graphic of the risk scenarios helps to identify three main areas (Fig. 7):

- *Avoidance Area*: the risk is not acceptable; it has to be eliminated or mitigated.
- *Mitigation Area*: the risk is within the risk policy, but still represents a threat; avoidance/ mitigation actions should be considered.
- *Acceptance Area*: the risk does not violate the risk policy and is negligible, and can therefore be accepted.

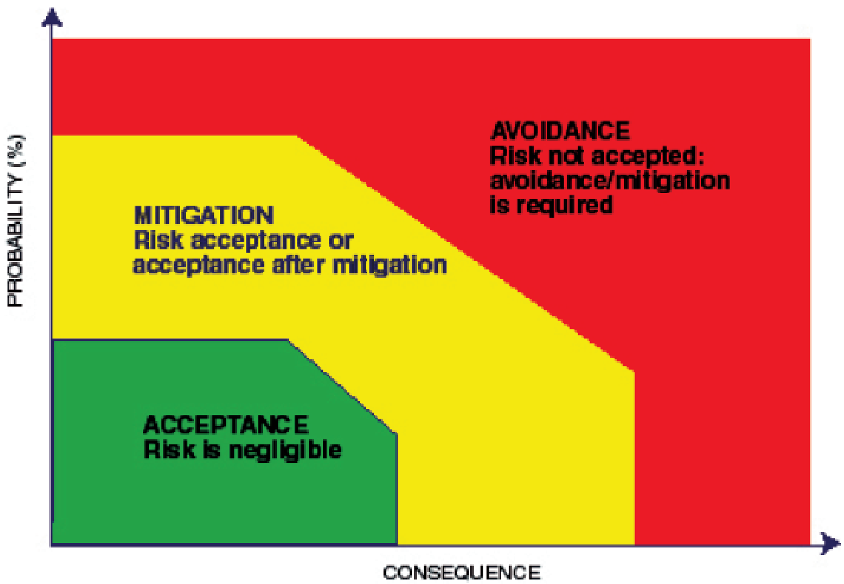

Figure 7. The risk decision areas

Another dimension of risk relates to time distribution (Fig. 8) and the period in which the risks are expected to occur and, therefore, the time left to act against them. Experience shows that the curve of risk distribution over time tends to be front-loaded due to the better perception of short-term risks by the staff interviewed.

Risk Policy definition

The Risk Policy is the main tool for prioritising risk scenarios. It identifies the principles, boundaries and constraints that drive the assessment and acceptance of risks. Generally, the policy is established at Programme level and it is part of the process for establishing programmatic baselines. The definition of a Risk Management Policy Baseline includes the establishment of criteria for:

- What are the goals?
- When is a risk acceptable?
- How to manage risk?
- How to control risk?

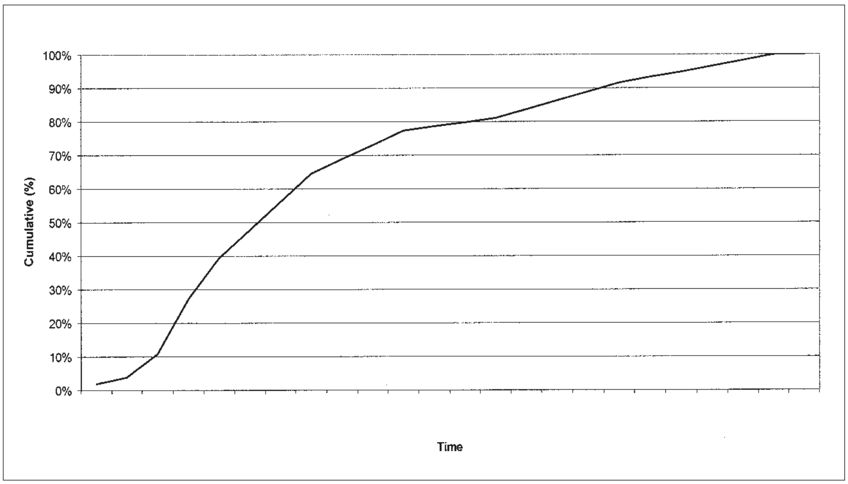

Figure 8. Typical risk impact time-distribution

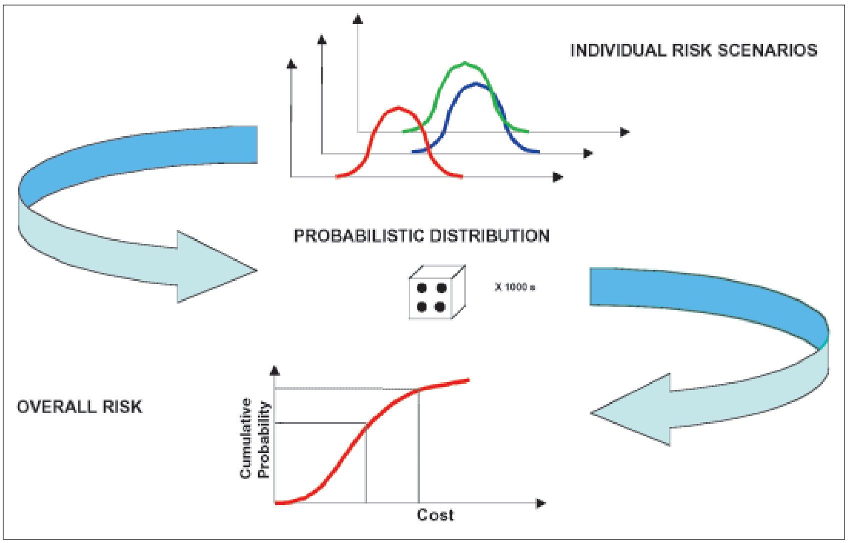

Figure 9. The Monte-Carlo computation

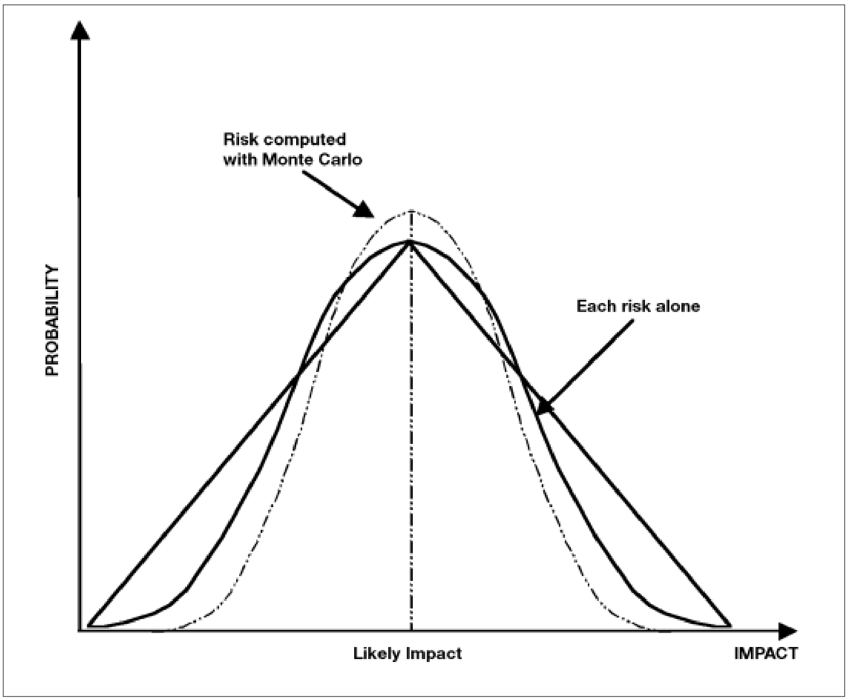

Figure 10. The probabilistic distribution of risk

This provides the opportunity to:

– establish goals with related levels of confidence for achievement
– develop concepts, strategies and tactics consistent with the levels of confidence
– develop agreements and contracts that are equitable in their apportionment of risk and opportunity
– avoid built-in budget and schedule overruns and shortfalls
– trade-off risks against opportunities
– replace reactive management by proactive management.

Contingency analysis

The purpose of the Contingency Analysis is to estimate the financial resources needed to cover all identified project/programme risks in an optimum manner. The Monte-Carlo simulation that is applied calculates the probabilistic distribution of the overall risk impact, starting from the single risk scenario. Each single scenario has its own distribution based on Likely Impact, Lowest Impact, Highest Impact, and a probability function. The most significant advantage of this method is that many independent items are treated as one set, and therefore the overall probabilistic distribution of risk is narrowed. The benefit of applying this method grows with the number of risk scenarios and/or projects/programmes involved in the aggregated analysis.

The total project/programme risk impact is the sum of the estimated scenarios obtained by generating a random probability and impact for each scenario and then adding them (Fig. 9). The profile of the distribution curve is narrower than that obtained simply by summing the distribution of each risk alone, due to the inter-dependency between the risks. Indeed, the probability that all risks would materialise at the Highest or Lowest Impact is very low (Fig. 10).

The cumulative probabilistic curve obtained by applying the Monte-Carlo simulation helps to select a confidence level related to a certain risk impact. The confidence level is a measure of the probability that the project/programme may actually incur an impact. If incurred, the impact is projected as the Programme/Project Risk Magnitude identified during the analysis. As shown in Figure 11, a line drawn from a selected probability factor (confidence level) on the vertical axis, across to the curve and then down to the cost axis, shows the cost estimated to be incurred at the selected confidence level. For example, a contingency selected at a confidence level of 75% means that the risk impact has a probability of 75% of remaining within the amount 'X'. A confidence level has to be chosen to determine a suitable

amount of funding reserve to cover the identified risks. The choice depends mainly on:
- risk policy
- available resources
- risk typology
- project/programme specificity.

The selection of a suitable confidence level is one of the major management decisions required to identify the contingency needed at programme or project level.

Risk management

All risk scenarios falling inside the 'Avoidance' and 'Mitigation' areas of the Probability-Impact Grid are, in principle, candidates for the risk avoidance/reduction process. The purpose of this step is to control the risk by implementing avoidance/mitigation plans leading to deletion of the risk or lowering of its magnitude. A risk can be reduced by implementing preventive and mitigation measures aimed at:
- eliminating the cause of a problem
- interrupting the propagation of a problem to an actual impact.

Typically, the Project Manager prepares the avoidance/mitigation plans, which may need to be submitted to a higher management level, depending on the degree of authority assigned to the Project Manager and the complexity of the issue. The avoidance/mitigation plans are assessed from a cost/benefit point of view to ensure that:
- the cost of implementation does not exceed the likely benefits
- there is a reasonable probability of success
- resources assigned to avoidance and mitigation actions are chosen such that they offer the greatest chance of success.

This step will result in one of the following:
- *Risk Resolved*
- *Risk Partially Resolved*, i.e. risks that still constitute a potential danger, but for which the impact is estimated to be reduced to acceptable levels
- *Risk Unresolved*, i.e. no mitigation plans can be devised, or the resources required exceed the anticipated benefits.

The result of this exercise is compiled in a report that includes:
- Programme/Project policy baselines
- Programmatic Risk Assessment Register, including 'potential risks'
- Probability-Impact Grid and trends
- Risk analysis
- Prioritisation list
- Contingency analysis
- Avoidance/Mitigation Plan implementation status
- Recommendations.

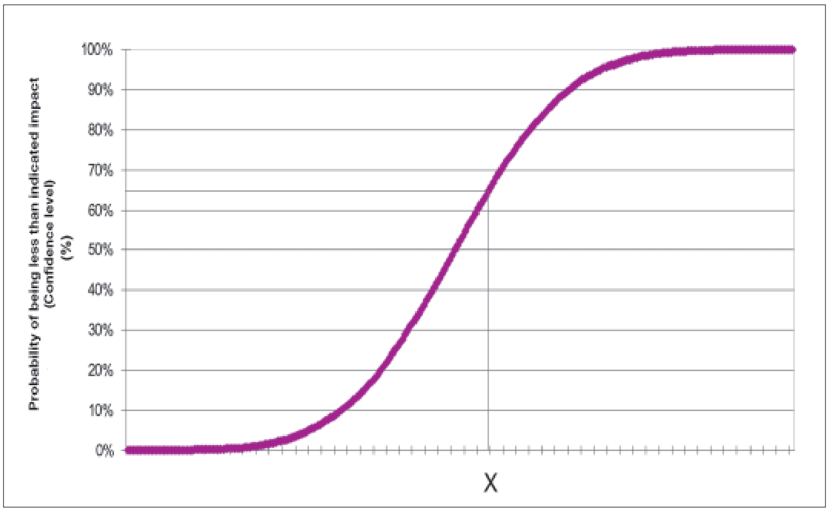

Figure 11. Contingency analysis

Last but not least, a database is created and maintained to ensure full visibility of the evolution of the Risk Management effort.

Conclusions

The Agency anticipates substantial benefits from implementing the above process in its major space programmes, in terms of:
- *risk awareness*: the most important aspect of the approach, supporting risk perception and control, and a common vision for the entire organisation
- *risk policy*: making project-management boundaries and constraints more explicit
- *risk estimation*: allowing more consistent and traceable estimation based on a systematic method of identifying risks and the repetition of the analysis cycle
- *risk control*: striving towards risk avoidance/ mitigation actions, and a confidence-level approach to contingency allocation.

The details of this process are documented in the Programmatic Risk Management Plan released for use in the Directorate of Manned Spaceflight and Microgravity. A simple software application to support data analysis is in preparation, and it will shortly be available via the ESA Web Site.

Acknowledgements

The authors wish to acknowledge the contributions provided by: Booz-Allen and DASA in the definition of the check-list for interviews; and AGF and Marsh in sharing their experience in applying the Monte-Carlo technique in the insurance industry.