JUSTIFICATION OF NEO IMPACT MITIGATION ACTIVITIES BY RISK MANAGEMENT

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ABSTRACT. The possibility of impacts of near-Earth objects (NEOs) on Earth is a typical high-consequence and low-probability risk. The relevance of this threat is often unrecognised by governments and therefore proposals for activities on NEO impact mitigation are frequently rejected. The Risk Management approach clearly categorises this risk as a "high-consequence - low-probability" risk, which requires at least "moderate" attention. The result of this analysis is that current world wide expenditures to prepare for the NEO impact threat (i.e. NEO search, orbit tracking, analysis of mitigation methods, etc.) are comparably low and should be increased significantly. The maximum expenditure estimates as defined by the Risk Management approach are given.

1. Basics of Risk Management

Risk Management as an integral part of Project Management is a formal process which allows to evaluate and compare different risks in order to identify the most important ones which should be mitigated in advance. A risk is defined as an event that has a certain chance to occur (probability) and negative effects (consequence). Solving risks in advance ("pro-active approach") requires less resources than solving problems, i.e. risks that already have occurred. Solving risks applied to NEO impacts means to prevent mankind from a (global) catastrophe [Friedman, 1997].

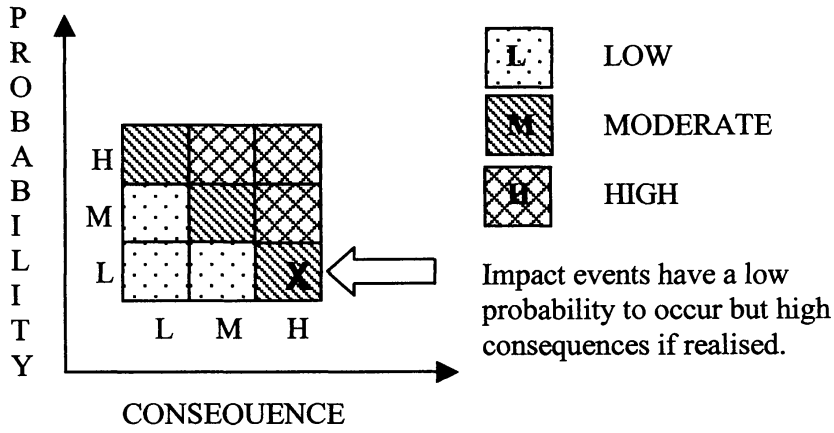

Fig. 1: Principle of risk level definition using a risk matrix.

The qualitative definition of the risk level depends on its probability of occurrence and its consequence if realised as shown in Figure 1. The impact risk in general is a "high-

consequence - low-probability" level risk. Thus, it is categorised as a "moderate" level risk which requires certain precaution actions as mentioned in Table 1.

Risk level (fig. 1)	Risk level definition (Project Management point of view)	Required actions with respect to the NEO threat
low	Minor impact to the program; monitoring but no need for major actions by now.	Tunguska-sized impactors should be detected and tracked, but warning time may be too short for mitigation; evacuation could be considered.
moderate	Aggressive management within current plan should keep these risks under control.	NEO detection and tracking is required for mitigation measures; preparation of mitigation actions by analyses by now; system development if required (long warning time is mandatory).
high	These risks require a change in the baseline or the implementation of new management processes to control them; should be brought to senior management attention.	NEO with non-zero impact probability is detected (for details see e.g. Torino Scale [Binzel, 2000]); immediate action required; international efforts; available analyses (as above) save time or even allow for successful mitigation.

Tab. 1 : Definition of the resulting risk levels and required actions.

2. Risk Management Applied to the NEO Hazard

Although most of us have no personal experience in NEO impact events or even meteorite falls we know today that the impact threat is real and the effects of km-sized NEO impacts will be catastrophic on a global scale. Calculating the average annual costs of these impact events shows that this risk should be considered as an important one. Considering the financial risk only, a basic rule is that the financial commitment for risk mitigation should not exceed the costs if this risk is materialised. This means that expenditures for preparation activities (without a tangible threat situation) should stay below the long time average costs due to impacts. However, average costs of 400 million US$/year due to impacts of NEOs larger than 2 km were estimated [Canavan, 1994]. This value is derived from the assumption that the world's total gross product of 20 trillion US$ per year will be lost over a period of 20 years (recovery time). This value is multiplied with the impact frequency of 2 km NEOs of 10^{-6} 1/year. The resulting number of 400 million US$/year is some two orders of magnitude more than the actual expenditures of roughly 5 million US$/year world wide for NEO detection and related activities.

This shows that the requested amount of about 50 million US$ in investment costs and about 15 million US$ of annual operation costs for a 25 year world wide search program using six telescopes [Morrison, 1992] is fully justified and should be extended by an amount in the order of some 5 to 10 million US$ per year for analyses of mitigation options in an international cooperation. Although there is no dedicated NEO defence program up to now more than 288 technical and scientific papers have been published on this topic since 1967 [Gritzner, 2001].

In case that an actual threat should arise it is justified to use the complete sum of preventable damages (saved costs) for threat mitigation (which could be up to $20*10^{12}$ US$ [Canavan, 1994]) if only the financial aspect is considered. Additionally, if human lives are considered, it is an ethical question whether each human live is invaluable or to assume a theoretical value such as a compensation payment. It is shown in Table 2 that the expenses for NEO mitigation activities are very low. When compared to expenses for air transportation safety or waste site clean-up (in the USA) per (expected) casualty. The USA spend about 3 million times more money for each casualty due to toxic waste sites than due to large NEO impacts (see right column). These selected examples demonstrate that the NEO topic is still underrated.

Risk area	**expenses for hazard prevention per year, million US$**	**expected/real world wide casualties per year**	**actual annual expenses per casualty, million US$**	**expected/real annual compensation payment for all casualties, million US$*)**	**relation of actual to compensation expenses per casualty**
NEO 60 m class	<5	50 [Chapman, 1994]	0.1	135	0.037
NEO 500 m class		30-300	0.17-0.02	81-810	0.063 – 0.0074
NEO 1.5 km class		3000	0.002	8,100	0.00074
aircraft accidents	1,178 (US**)	1131 (world wide [ASN, 2000])	>1.04	3,053	0.385
waste site clean-up	6,000 (US only)	1 (US only) [Gerrard, 2000]	6000	2.7	2222.22

*) *average compensation payment per casualty in civil air transportation accidents in the USA is $2.7*10^6$ US$ [Aviationinfo, 2001]*

**) *FAA safety funding (goal: reduction of US aviation fatal accident rates by 80% from 1996 levels) [FAA, 2000]*

Tab. 2: Annual world wide expenditures for risk mitigation, absolute and per casualty.

The two graphs of Figure 2 show the actual expenditures for NEO activities (in the order of 5 million US$/year) compared with the required sum ("req.") for a world wide search program, and the maximum expenditures as considered by the risk management approach for the two cases that only financial (f) damages are relevant (400 million US$/year) or that only human casualties (c) are considered with a sum of 2.7 million US$ each.
The graphs in Figure 2 use different scales to present all four results in one graph (logarithmic scale, left) and to illustrate the real relation of actual costs to the upper limit (linear scale, right).

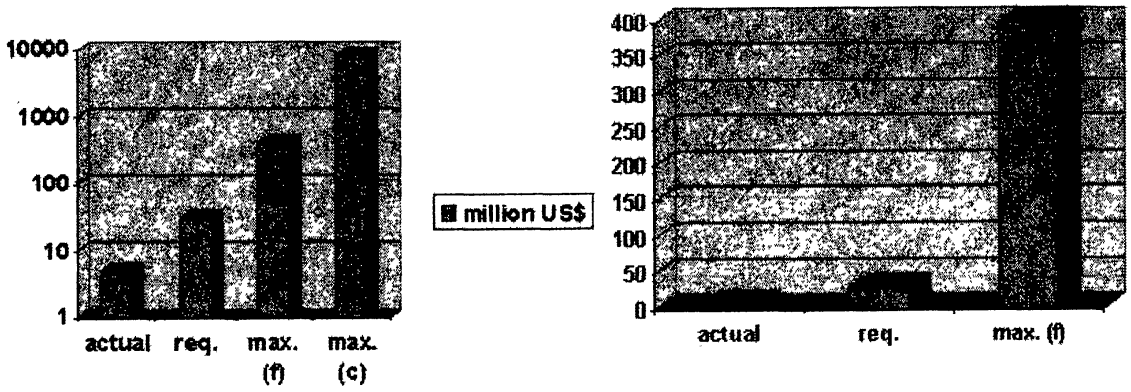

Fig. 2: Comparison of actual, requested, and maximum annual expenditures for NEO threat mitigation (left: log. scale, right: linear scale, (f) = financial aspect, (c) = casualty aspect).

3. Conclusions

The present study demonstrates that the current expenditures for NEO hazard analysis and mitigation are negligible low when compared to the efforts justifiable by the Risk Management approach. Current activities (NEO search, orbit tracking, analysis of mitigation methods, etc.) and the proposed world wide search campaigns are fully justified, too, even if *only* financial aspects are considered. Although NEO impacts are rare events, they have the potential to cause global catastrophes and they therefore should receive more attention and financial support. A "pro-active" approach is mandatory to solve the impact problem. A reaction on events after their occurrence will be a catastrophic mistake in this case.

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