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Risk Management and Insurance Solutions for Space and Satellite Projects

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1. Introduction

Space travel can be seen simply as one area of the development and use of high technology. Nevertheless, partly because of its irradiation effects on electronics and the enhancement of raw material, many view it as a key technology. The generally very complex systems, the equipment, the parts and the control mechanisms require extreme measures as far as performance and reliability are concerned. This is because running them is very costly and break-downs should be avoided. The limited transport capacities also need to be utilized as efficiently as possible. Additionally, due to the difficult conditions in space (temperature, radiation, highly sensitive control processes, large distances to ground control), space missions have to follow a rigid and precise schedule. The insurance industry can help in managing private investment risks against property, financial and liability losses. The insurers, however, need to make use of particularly careful, anticipatory risk valuations, competent inspectors and highly specialized know-how in pricing and claims handling.[1] The insurance industry can be a technology pioneer in three ways[2]:

(1) By insuring venture capital for large technology projects.
(2) By improving the acceptance of technical products where damages resulting from these products are paid by the insurer.
(3) In having a direct impact on technological development by providing loss control and loss reduction tools.

In this paper, we will illustrate several insurance solutions for large space and satellite projects. Additionally, and in line with other economic disciplines, we will present an integrated management concept that will help improve the reliability of complex technical systems. Moreover, we will develop a checklist for the efficient risk management of space and satellite projects.

We have identified three different categories by which one can distinguish satellites according to their use: scientific satellites (for example, for research of the earth and its immediate surroundings, for astrophysical measurements and space observations), military satellites and task-oriented satellites (for example, communications, earth explorations, weather and navigational satellites). Only the latter category of satellites is currently being placed as an insurable risk on the insurance market, the focus being on communications satellites.

With regard to the chronological and technical execution of a satellite project, we can

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distinguish five different periods (see Table 1). Periods one and two (production and transport) can be insured using some of the traditional types of insurance: commercial property insurance, technical insurance and marine insurance. The main problems of space project insurance arise in periods three, four and five (pre-launch, launch, and in-orbit). The insurance industry has acknowledged this and has come up with a special type of insurance – space travel insurance.[3]

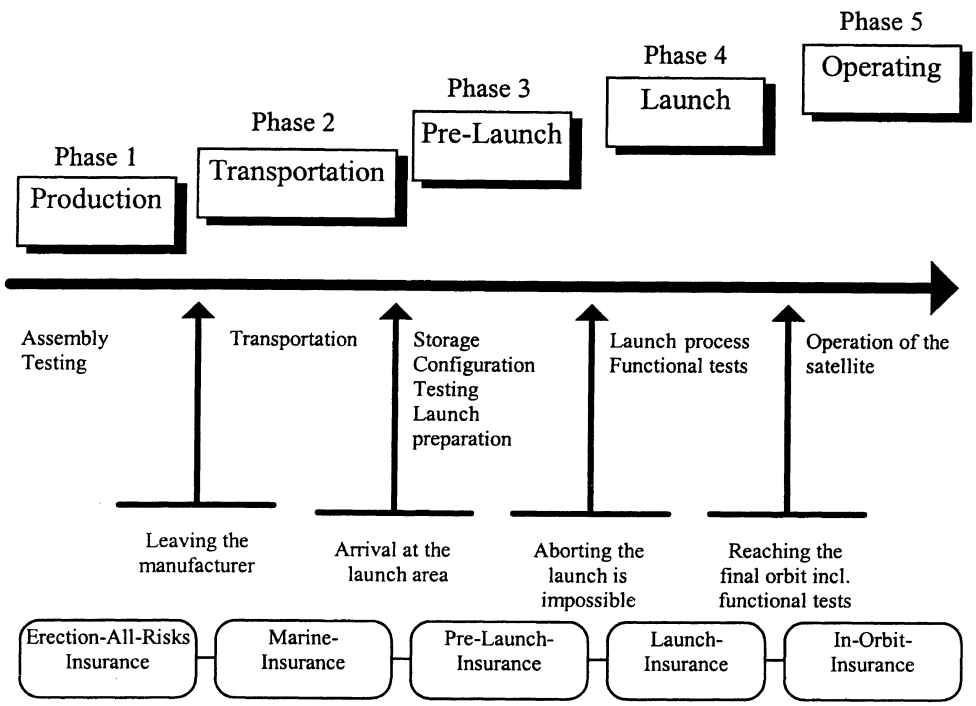
Breaking up the different periods of a satellite project chronologically allows different types of insurance and possible insurance solutions to be matched with the individual periods. It also reveals insurable risks in a broader sense.

2. Property insurance

Pre-launch insurance

Pre-launch insurance or pre-ignition insurance is an all-risk coverage for property losses of satellites and their launch missiles in the pre-launch period, that is, during storage in the launch area, the configuration of the satellite launch measures and the deployment of the satellite on the launch missile as well as during the whole launch preparation.[4] Coverage usually starts as soon as the insurable items have been offloaded at the insurance location (for example the launch platform), that is, when the actual offloading has finished and a final

Table 1:
Periods of space travel insurance



acceptance review has been completed. Coverage ends when the satellite property rights are transferred from the manufacturer to the buyer or, at the very latest, when aborting the launch is no longer possible. The point at which the coverage ceases is thus dependent on what kind of launch vehicle is being used. It is either the planned ignition of the fossil fuel missiles – as with the Space Shuttle – or the opening of the recoil clips a few seconds *after* the ignition, as with the Ariane missile. Hence the pre-launch insurance often covers the full risk of launch missile failure, although only for a relatively short period of time. When a launch is aborted coverage can, however, be reinstated before the transport vehicle leaves the launch area with the load (post-abort coverage).[5] From an insurance standpoint, the risk evaluation of the launch preparation – large amounts of highly explosive material are used when the missile is gassed up, for example – requires an extensive and highly specialized knowledge which is to be found in the space travel insurance market. The launch preparation encompasses a potentially large cumulative risk: the missile, the satellite, and the launch platform. It appears logical that the pre-launch risk should be managed by the specialized space travel insurance market. However, pre-launch risks are mostly covered by the marine insurance market. The rates on line currently amount to less than 0.5 per cent of the purchase value of the equipment. This has led some of the German insurers to switch to more restrictive underwriting policies.

Launch insurance

The launch insurance is an all-risk coverage for property losses and losses in function of the satellite and the launch missile which occur during the launch process, that is, during the entire launch activities when the missile is to reach its planned eclipse, followed by functional tests which usually last several months. The only losses excluded from coverage are those which result from or are due to war, anti-satellite weapons, confiscation, radioactive contamination, electromagnetic or high frequency disturbances, and intent. Here we found similarities with commercial air travel insurance. The coverage encompasses three sequential periods which are characterized by specific problems and loss potentials.

The first period starts at the contractually agreed upon point in time $t = 0$, when the pre-launch coverage ends. The launch missile system alone is critical for the success of this period. Any failure in the transition between the different launch periods results in the total failure of the missile launch into orbit. The first period of the launch insurance ends with the separation of the satellite from the last missile stage.

The second period of launch insurance – the stationing period – in which the satellite reaches its final eclipse position on its own begins with the ignition of the apogee engine and ends when the satellite reaches its planned position in geostationary orbit. During this period, the reliability of the apogee engine used plays an overly important role.[6]

The third period, also called early-in-orbit or commissioning/test period, begins with the satellite reaching its final geostationary position in orbit. This third period includes:

- solar array and antenna deployments
- in-orbit testing and commissioning
- initial period of in-orbit life, once the satellite has been declared operational after completion of the commissioning period
- the first two eclipse periods.[7]

For the commissioning/test period, besides the subjective evaluation from the satellite manufacturer, it is recommended that mathematical analyses are carried out and the dependability of the satellite assessed. In this evaluation one has to consider the technical

complexity, for example, the number of parts in relation to their weight. Practice has shown that the three periods mentioned above can be pooled under a single coverage – the launch insurance.

However, in some cases these periods can also be insured separately. Coverage usually ends 180 and 365 days respectively after the start. In 1996, premiums were as low as 15.8 per cent for the Arabsat 2A and 2B, both launched with an Ariane 4 missile, and as high as 21.05 per cent for the satellite Nahuel 1B which was launched into orbit on the Chinese Long March 3. When considering the maximum limit of insurance which should be provided, the costs incurred by the insured are the most critical criteria. These include the replacement value of the satellite, the missile and accessories, but above that the costs incurred for relaunch. Besides the hardware this means all the other necessary expenses, and in particular the very costly launch service. In case of loss, the insured party usually bears the self-retention that is defined in real dimensions, such as the loss of a certain number of transponders or a certain number of years in the satellite's life expectancy. The launch is only regarded as a success if the pre-set parameters have been met in all three periods. In the case of mechanical damage or the satellite not having reached its planned eclipse, the launch ends in a total loss. The overwhelming majority of all launch insurance losses are total losses. It is considered a partial loss if the satellite functioned only partially, for example if a certain number of transponders failed or the satellite's life expectancy was reduced due to higher fuel consumption when the satellite was corrected in its eclipse. In these cases, and depending on the degree of malfunction, a certain amount of the insurance limit becomes due. This is why the policy includes partial loss formulae for several partial loss scenarios. With these partial loss formulae one can calculate the reimbursement due as a percentage of the limit of liability (see Table 2).[9]

If the malfunctioning due to a partial loss exceeds a certain limit set in the policy, this loss is considered a constructive total loss. This threshold is not usually reached very quickly, as reimbursement for a constructive total loss should only be provided when the malfunctioning due to a partial loss is so significant that the satellite no longer meets the requirements of the insured and needs to be replaced.[10] In the case of a constructive total loss, the insurers usually require the insured party to transfer the property rights of the satellite to the insurer. Alternatively, the insurers will receive any revenue that can still be generated from a satellite which functions only partially. In Anglo-American terminology this practice is called "salvage". In launch insurance, the insured party is usually the satellite carrier, such as Deutsche Telekom, who purchases the satellite from the manufacturer and launches it with a missile of choice. More recently, there have been developments whereby the satellite carrier (buyer) seeks to take over the satellite in orbit once it is ready to operate or, in other words, turn-key. With this delivery-in-orbit practice the launch risk is transferred back to the satellite manufacturer. For an insurer, negotiating the policy terms and conditions and servicing the account becomes more complicated, especially the handling of partial loss claims.

In-orbit insurance

The in-orbit insurance or "life insurance" is also an all-risk policy with pre-set total loss limits.[11] It starts when the satellite begins to operate, and covers any total or partial loss of a satellite or its functionality in orbit where the satellite serves as either a communications or an earth exploration satellite. The value to be insured is initially correlated with the replacement value, in other words the limit comprises the costs for a replacement satellite including the costs for a relaunch. The longer the satellite has been in service the more prone it becomes to

Table 2:
Examples for partial loss formulae

Partial loss (loss of fuel)

If the amount of fuel aboard the satellite equals 50 kg or less, the satellite is considered a total loss. If the amount of fuel amounts to less than 97.5 kg but more than 50 kg, the satellite is considered a partial loss by applying the following formula:

$$PL_{prop} = (97.5 - M/97.5 - 50) \times 100$$

where PL_{prop} equals the amount of reimbursement due (in per cent). M equals the amount of fuel remaining aboard the satellite.

Partial loss (transponder failure)

In case of transponder failure, US$ 1 million will be reimbursed for every failed transponder provided that no total loss has occurred. For C-Band transponders this amount will only be reimbursed beginning with the sixth transponder failure

Partial loss (energy)

If the electrical power available aboard the satellite equals no more than 1,000 Watts, the satellite is considered a total loss. If the electrical power aboard the satellite amounts to less than 1,495 Watts but more than 1,000 Watts, the satellite is considered a partial loss. This partial loss is calculated by applying the following formula:

$$PL_{power} = (1,495 - P/1,495 - 1,000) \times 100$$

where PL_{power} equals the amount of reimbursement due (in per cent). P equals the amount of electrical power remaining aboard the satellite.

losses in function which reduce its value. To avoid limits which are too high on a satellite that is losing value, the limits are gradually lowered. Hence, coverage is granted for a certain period in reasonable relation to the satellite's life expectancy. For new satellites the policy period is usually limited to three years. For the policy renewal, in general every year, the insurer often asks for a "health certificate", which requires an extensive reassessment of the satellite's technical condition and all prior functional disturbances. The in-orbit insurance is regarded more highly by insurers than the launch insurance, because at the beginning of the policy period the satellite has already reached its planned position on the eclipse and completed several months of testing. Potential major flaws can usually be detected during the test period. Therefore, such losses would be handled by the launch insurance. Total losses are relatively improbable; the major risk of in-orbit insurance lies in partial losses, the criteria of which need to be laid out specifically in the policy.[12] The focus of underwriting such insurance is on estimating the life expectancy and reliability of the critical systems and components. Furthermore, because of the wide range of insured risks, the risk diversification in in-orbit insurance is much greater than in launch insurance. The rates on line for in-orbit insurance during 1996 varied between 1.55 per cent for the Thor 1 satellite launched on 18 August 1990 on a Delta 6926 and 2.68 per cent for the Arabsat 1C launched on an Ariane AR4 on 26 February 1992.[13] The latter has now been declared a total loss. As with launch insurance, in the case of destruction or total loss of function the satellite will be regarded a total loss or a

partial or constructive partial loss if the capacity or the life expectancy has been reduced. To determine the amount of the partial losses, partial loss formulae similar to those for launch insurance are used. The deductibles can be assumed by the insured through a certain number of transponder years or, as with the satellites ECS 2,4 and 5, through a co-insurance percentage of the total limit. Transponder insurance is a special form of in-orbit insurance which we will discuss only briefly. This partial coverage insures against property losses or losses in function of transponders. Such an insurance is needed when, for example, it is not worthwhile for the insured party to install its own satellite system. Instead, the insured party can buy or lease individual transponders on an existing system that is fully utilized or being used by other carriers just for this purpose. The various services provided (protected service, unprotected service and pre-emptible service) require particularly careful underwriting and risk management.

3. Pecuniary loss insurance

Loss-of-revenue insurance

The economic loss from the damage of a satellite at launch or in orbit can exceed the mere property loss if revenue is lost due to malfunctioning of the satellite.[14] A standard coverage for insurance against such financial losses has not yet been established on the market. Generally, this type of coverage is similar to the traditional business interruption coverage as it exists for fire and machinery breakdown insurance. It covers lost business income and current operational expenses. With satellites, reimbursement should only be granted for business income which would have been generated had the satellite loss not occurred. For this, sufficient proof needs to be provided. Agreements on lump-sum reimbursements for lost business income under launch or in-orbit insurance should be avoided. For example, if a satellite which was not fully utilized malfunctions, or if the malfunctioning satellite's tasks can be completed by another satellite which is owned or leased by the insured party, then the carrier suffers little, if any loss in business income. For such financial losses resulting from property losses, only the standard business interruption insurance principles should be used. Besides the losses in business income due to business interruption, the satellite carrier could also face additional costs for leasing replacement satellites or having to re-set thousands of receiver antennas. These costs can also be covered under the above described insurance.

Incentive payment insurance

The demand for incentive payment insurance usually comes from the manufacturers of space travel products. The buyers negotiate extensive and very detailed specifications with the manufacturers concerning the satellite's function and life expectancy. These specifications are laid out in great detail in the delivery contracts. Payment of the full purchase price is often dependent on meeting all the specifications. This is why the buyer pays only the minimum purchase price prior to delivery. Sequential payments as so-called "incentive payments" are only rendered if the satellite meets the agreed technical requirements. By buying the so-called incentive payment insurance the manufacturer can insure against the loss of the difference between the down payment and the full purchase price of the space travel product. The term "Incentive Payment Insurance" is rather narrow, as the payment of contractual fines or punitives by the manufacturer can be included in the coverage instead of or in addition to the

actual incentive payments, depending on what has been agreed with the insurer. This type of coverage is not without problems because it is, in essence, equal to warranty insurance and difficult to separate from uninsurable business risk. It should only be offered if the specifications guaranteed in the sales contract have been carefully reviewed by an expert. The subjective risk can be somewhat controlled by a large enough co-insurance clause. Another form of warranty insurance for space travel and satellite projects is launch-risk-guarantee insurance. It is offered by space companies such as Arianespace and offers warranty for the launch. If the satellite does not reach its planned eclipse, if it is destroyed or if it malfunctions and if any of this is caused by a malfunction of the launch missile, then Arianespace as the satellite carrier provides a free re-launch or reimburses an agreed amount. For this purpose, Arianespace has set up its own captive reinsurance company (S3R) and offers the services described above at rates between 13.5 per cent and 14.5 per cent. For re-launches, Arianespace charges 13.5 per cent whilst for cash reimbursements it charges the higher rate of 14.5 per cent (or 7.4 per cent more).[15]

4. Opportunities and limitations in insuring space travel risks: main problems

The evaluation of the technology involved becomes increasingly difficult for insurers, so that even leading and well respected companies sometimes reach the point where they can no longer estimate *ex ante* the development risk. Although we generally view satellite and space travel risks as insurable, there are significant problems for insurers and reinsurers with respect to coverage and the preparation of such large technical projects. These problems comprise technical as well as actuarial issues. What are the key questions, the difficulties and limitations of insuring satellite and space travel equipment?

The space industry, brokerage houses, and primary and reinsurers have repeatedly sought innovative concepts for the future. When describing the risks and the various types of coverage we already discussed several issues that make the insurance of satellite and space travel risks difficult. It is mainly the following typical characteristics of a space insurance portfolio which create substantial problems:

- The extremely small number of insurable events means high chance variations;
- Continued technological development means lack of technological homogeny and a large risk of technological change;
- Extremely high relative loss occurrence;
- Very large limits;
- Large spread of limits in connection with a high risk of total loss;
- Risk of accumulation of total losses resulting from the launch of several satellites at a time.[16]

With such portfolio characteristics it will continue to be difficult for primary and reinsurers to come up with a balanced, calculable insurance programme that is also affordable for the insured. The result of having so few insured events (approximately 150 during the last ten years) is a relative lack of statistical data, making a balanced rating structure overly difficult. Because of rapid technological developments, the foundation on which risks are evaluated is changing constantly. Furthermore, besides the multi-faceted technological risk environment and its impact on actual insurance policy, the price for coverage and the insurability are heavily dependent on a strict adherence to basic principles, such as proof of loss (alleged and actual), use of appropriate definitions of loss, partial loss agreements and salvage value clauses. The big capacity problem which results from the enormously large values to be insured will be

discussed in the following section. Moreover, the timely availability of insurance can be critical to the financing of such large technology projects. In order to obtain financing from banks and/or other creditors, the satellite carriers often need to have an insurance policy available years in advance. Such an insurance policy, however, is difficult to obtain early in the game as the insurers prefer to not get locked in due to the large risk of technological change.

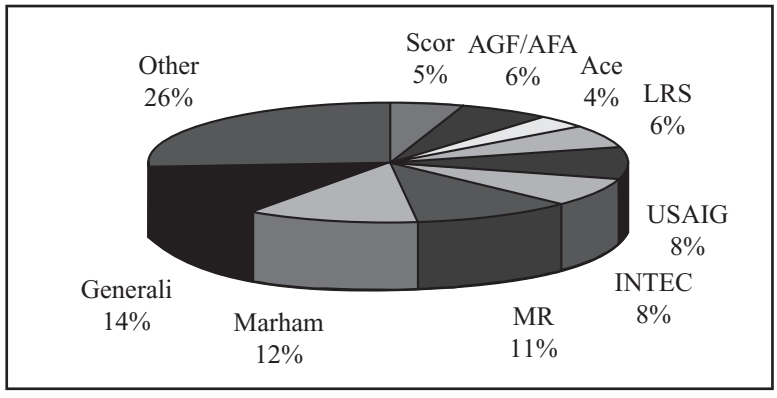
5. Global market capacities

In looking back to the mid-1980s and the lack of capacity, we should point out that the insurance industry 'paid' for its lack of thorough risk assessment with heavy losses. Since several insurers withdrew capacity from the space insurance market because they did not view these risks as insurable or because they simply did not have or could not afford enough expertise to evaluate these risks properly, capacity problems arose.[17] Today's market is characterized by an oligopolistic structure, as Table 3 shows. Nine insurers or insurance pools provide 74 per cent of the market's capacity. The current global market capacity for a single launch amounts to approximately $650 million, a significant increase over 1995. Forty launches in 1996 generated a gross premium volume of $850 million. This figure compares with a claims volume of about $650 million.[18] For in-orbit coverage, the worldwide capacity currently amounts to about $300 million. Compared with the 1980s, there is now sufficient capacity for both launch and in-orbit insurance.[19] Problems could arise, however, if the values to be insured continue to increase for dual launches. Moreover, it remains to be seen how the insurance industry can provide this capacity most efficiently and whether the tools available to insurers need to be complemented. Professional reinsurers in particular are asked to adopt their traditional roles with respect to accumulation issues.

6. Risk management for space and satellite projects

With the large total losses of the 1980s in mind, the insurance industry had to address the question as to whether these complex technical satellite and space travel systems are

Table 3:
Leading insurers and their capacities in 1995/96[20]



manageable from an insurance perspective.[21] Greater reliability in commercial space travel, as demanded by insurers, became a necessity. By using the widely published launch missile failure data, and making a learning curve analysis which compares the cumulative portion of launch failures in relation to the number of starts, a better picture of the risk involved may be obtained. This launch failure data is of only limited statistical value and should not be associated with the loss experience of the insurers. However, it does provide a solid base for thorough risk analysis and the development of customized insurance programmes. Since the information is mostly based on data and assessments from the manufacturers, a serious issue known in the insurance industry as "moral hazard" complements the list of aforementioned problems. In order to gather, evaluate and manage all risks involved fully and systematically, we recommend dividing the whole risk management process into three steps: risk identification, risk analysis/risk valuation, and risk control. With respect to satellite and space insurance, these three components of risk management are above all influenced by two factors:

- What kind of missile system takes the satellite into orbit?
- What kind of space mission is it?

The goal is to come up with a risk description that lists the measures and opportunities for identifying, minimizing and avoiding the risk. The risk identification is more like a snapshot at one particular point in time, when one assesses whether new risks have arisen or whether existing risks have changed in scope, or when previously unknown risks are identified. When insuring large, highly innovative technical projects, the focus is on proper risk analysis and valuation. The small number of insurable events, their technical heterogeneity and the wide spread of insured values, the incomplete data or the lack of cost-effective means to obtain information complicate the risk analysis process for the risk manager. To obtain the two critical measures, loss frequency and amount of loss, auxiliary measures are being used, such as "probable maximum loss" ("PML"). The satellite or the launch missile are classified into different risk categories to be able to fully utilize the PML and loss occurrence probability data when analysing a number of different objects. In a risk analysis, numerous factors need to be considered. The coverage needs to be customized to meet both the manufacturer's and the user's contractual agreements. Additionally, one needs to compile a precise description of the satellite's and the missile's configurations during the different stages of the risk histogram as well as a precise description of the tasks to be completed. This includes all systems, budget figures for fuel, load and electrical power, information about the exact position of the satellite during the different test stages, information about the production and assembly processes, lists of suppliers and failure ratios. Like Greenberg/Gaelick[22] we will structure the risk analysis by using a checklist, as follows:

(1) Meeting the launch deadline.
    This is particularly important with respect to the launch vehicle used. Technical problems during the pre-launch period could negatively influence the risk in subsequent periods.
(2) Possible launch delays.
    See 1.
(3) Time required by the satellite to travel from the apogee eclipse into the geostationary orbit.
    One should compare the timing with other projects. Additionally, one should compare the data with the reliability analyses and the experience of apogee engine manufacturers.
(4) Number of comparable satellites in use.

This is primarily important when deciding whether to write such a risk and when calculating a premium.

(5) Number of the satellite's narrow and broad band transponder groups.
When analysing the risk one has to forecast the transponder's expected life expectancy and assess the comparability with other transponders already in use in order to utilize such experience in the risk assessment. Special attention is to be directed at the capacity divergence between narrow and broad band transponders.

(6) Reliability and average life expectancy of each transponder.
This includes testing each transponder for reliability, followed by an assessment of the average life expectancy within the group, and finally calculating the standard deviation of average life expectancies. Such analyses are critical with respect to the definition of the term "constructive total loss".

(7) Reliability of the subsystems.
The analysis of the missile's and satellite's subsystems is critically important to the successful completion of all mission phases. The data provided by manufacturers and users need to be supplemented and supported with the insurer's own data and information.

(8) Annual demand for narrow and broad band transponders for any communications application.
Such an assessment is made to calculate the number of so-called replacement transponders that are being used if the regular units fail. Particularly with respect to constructive total losses it is important to know the exact number of replacement transponders necessary to maintain a normal, "loss-free" transmission.

(9) Costs of the launch period in relation to the costs of the satellite.
This aspect is only to give an indication of whether the relationship seems balanced. If the costs of the satellite are disproportionally high compared to the costs of the launch period, then the risk manager has to check the technical equipment of the satellite once again. This is because highly innovative technology without a long, proven track record may be in use on board, thus increasing even further the prototype risk and hence the probability of a loss.

In conclusion, for a risk manager *every* single satellite and space project is a new risk; only some individual aspects are comparable to previous risks because of the technical differences. The "checklist" presented should be viewed only as a minimum requirement which does not claim to be complete and which needs to be continuously adjusted in accordance with technological innovations. Risk influencing instruments, such as "risk control" and "risk financing" are not addressed in this paper. However, risk control elements such as risk avoidance and risk reduction particularly should play a significant role in satellite and space technology.[23] Risk analyses are the foundation for measures to maintain high standards of quality, and are hence important for achieving a superior standard of safety and reliability. This information is of great importance for the actuarial evaluation of the risk and hence for the pricing and the setting of the rate on line and the capacities available.

7. Total Quality Management as an integrative concept

Since the problems with the coverage and pricing of satellite and space risks can be attributed to the special risk structure, they can only be eliminated if the risk characteristics that make an insurance solution more difficult are eliminated or at least reduced. One possible

solution is the Total Quality Management ("TQM") concept which involves a comprehensive quality approach as a cross-functional way of thinking. This corporate strategy focuses on meeting certain quality goals, with such quality goals being derived from customer requirements. TQM in itself means to view quality from the customer's or recipient's perspectives. The customer determines the quality standards, the quality criteria and the level of quality required. In principle, the economic calculation is quite simple: in order to be able to offer a near to flawless product, more effort than used to be considered normal is made to search for the sources of product flaws. Such sources of failure are then eliminated, reducing the cost of flaws.[24] Quality maintenance as loss prevention must *not* be considered a cost factor. It has to be the main philosophy of all employees for an error-free programme.[25] The customer will detect any flaw, meaning that the error-free principle is not luxury; it is a necessity. This is because quality from the beginning costs less than costly repairs which damage one's image. The quality tools range from simple error collection lists and quality rule cards to cause-and-effect and portfolio diagrams as well as employee training sessions. An additional instrument which promotes and supports trust and cooperation among business partners is the so-called "active risk survey", where insurance brokers and companies participate in the manufacturing process of satellite and space equipment by visiting the different locations. In this way modifications and problems can be addressed directly and solutions be discussed, since all parties involved have the same amount of information available.

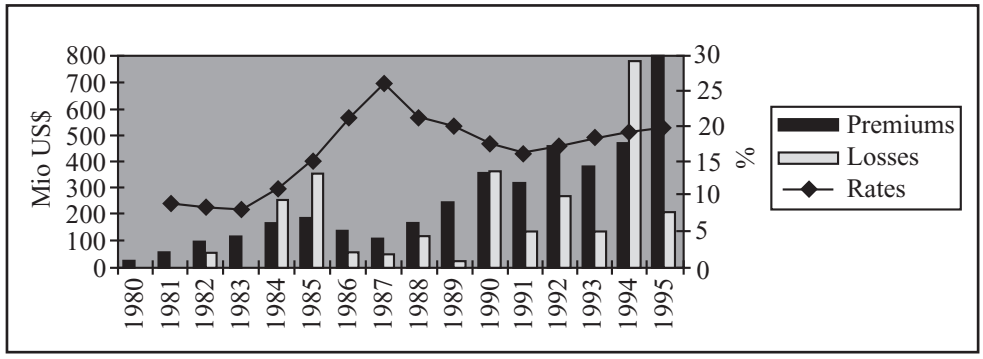
Total Quality Management should therefore not focus exclusively on the space industry, namely on manufacturers and contractors. A long-term corporate strategy also requires TQM in the terrestrial sector, that is in the insurance and financial service industries as well as in government administration.

8. Closing comments

"In all major capital projects, of whatever kind, money is the driver. Return on investment is the king. In space, the availability of the necessary resources is also often a function of political will."[26] This statement is true for all parties involved in the satellite and space business. Any prognosis for the next few years needs to be viewed in light of political unrest, ethnic disputes, and economic problems such as unemployment and enormous government budget deficits. This virtually makes it "speculation". Nonetheless, we want to attempt to show future trends and problems that the insurance industry will face when insuring satellite and space projects:

- For 1996, the estimated global premium income on the space insurance market amounts to about US $850 million whereas the global market capacity for launch insurance is estimated to be US $650 million.[28] Considering the good results in 1995 (net premium excess of about US $600 million, see Table 4) and 1996 (net premium excess of US $200 million), one could expect some pressure on the premium side.
- The rapid technological developments, the use of Russian Proton and Chinese Long-range missiles as well as the deployment of new satellite systems such as Iridium or Odyssey "will present the brokers and underwriters with fresh challenges in both risk assessment and coverage design".
- The development of increasingly heavy satellites (3.4 tons) on the one hand and the so-called "lightsats" or "minisats" which weigh just a few hundred kilograms on the other. The latter are particularly dangerous with respect to the problem of "space debris".
- Increase in the satellite's transmission capacity.

Table 4:
Premiums vs. losses vs. rates on line in launch insurance[30]



- Increase in the satellite's life expectancy and demands by manufacturers to extend the coverage period that goes with it.
- An update and revision of policy wordings with respect to the issues "return/refurbishment after the claim settlement", "notification and proof of losses" and "representation of the status at the end of the risks" seems necessary in the near future.[29]
- Increase in lack of technological homogeny of satellites.
- Aggressive price competition with Russian and Chinese insurers such as China Pacific Insurance Co.
- Increase in the complexity of the satellites and hence in the value to be insured. Additionally, one could expect an increase in the "launch service costs" so that the limits of liability will increase even further.
- The problems involved in the change from technical underwriting to cash flow underwriting due to increased capacity.
- The "Leonid" meteorites swarm expected for 1998, 1999 and 2000 could lead to accumulation problems.[27]

Theoretically, the opportunities in satellite and space technology are unlimited in the best sense of the word. In reality, however, there are problems faced not only by the manufacturers and users of such products, but also by the insurance industry, which has had to go through a painful learning process when insuring large technical projects over the past few years. An additional increase in the reliability of satellite and space technology and improved co-operation between all parties involved in such large technical projects form the foundation for the future. Through customized coverages, global risk diversification and long-term underwriting policies in connection with appropriate premiums which include add-ons for incurred but unreported losses, private satellite and space risks can be insured with sufficient capacities today and in the future. The insurance industry does its share to assure technological progress and underlines its importance in the future development of commercial space travel.

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