Satellite pre-launch insurance: Technological advances reduce risk for underwriters. Discuss.

by Donna Young, January 2002

Satellite pre-launch insurance has been consistently profitable over the long term. However, it has not, as yet, been the subject of detailed research. Anyone considering such a specialist issue needs a full understanding of the technical terms and the precise definition of 'risk' in this context. I have explained the key terms in Appendix 1 and would suggest that readers make themselves familiar with these before embarking on the main text.

In order to assess satellite pre-launch insurance, an analysis of satellite launch vehicles, launch sites and manufacturers is essential. That said, this process is not directly connected with arguments for or against the statement in the title and so is not included in the main text. However, the importance of this subject must be acknowledged and Appendix 3 includes a discussion of variation in risk associated with the major launch vehicles, launch sites and manufacturers. This should be read alongside the main text for a comprehensive analysis of satellite pre-launch insurance, technological advances and risk.

Technological advances reduce risk to underwriters

This section begins with a general discussion of how technological advances reduce risk. It will be followed by specific examples taken from each stage of the satellite's pre-launch operation.

There are a number of powerful arguments to support the statement that technological advances reduce risk to underwriters. The basic premise is that improvements in technology, science and information ensure that a satellite is assembled, tested, transported and launched in an environment of controlled certainty. Technological advances deliver scientific data and technical information. This can be used to monitor risk and provide a transparency of working which enables a wholly risk-managed operation from the beginning to the end of coverage.

Even more important is the wealth of knowledge and experience which technological advances bring to the satellite industry. This industry has 40 years' experience assembling, testing, transporting and launching satellites. The European Space Agency states that, in Europe, such operations have become "normal everyday activities"[i]. The expertise and experience obtained from the technology of the past is developed and improved upon for the technology of the future. This skill and knowledge, driven forward by technological advance, is a primary factor in reducing risk to underwriters.

This argument is supported and amplified by the relationship between government agencies and commercial interests. These sectors work together to develop innovations in satellite technology. The three major government agencies in the satellite industry are the European Space Agency (ESA), representing the countries of the European Union, National Aeronautics and Space Administration (NASA) in the United States, and the Russian Aerospace Agency (RAA).

ESA, NASA and RAA are pioneers of spacecraft development. They are important to industry as they share their groundbreaking technology with the commercial satellite enterprises within their region. ESA states "Euro companies take over and develop the applications pioneered by ESA... Arianespace for launches and Eutelsat for telecommunications"[ii]. Pre-launch underwriters in the London market insure these commercial entities.

NASA declares one of its major aims as ensuring that it "commercialises technology". NASA describes its commercial technology network as "providing unique expertise and services to US enterprises, facilitating the transfer, development and commercialisation of NASA-sponsored technology"[iii]. The London market insures the US commercial enterprises that benefit from NASA technology.

It should be noted, however, that because of the strict rules set down by the International Traffic in Arms Regulations (ITAR), some technology that remains with the government agencies is not passed on to commercial interests.

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The sharing of information by NASA and ESA with their corresponding commercial industries in the USA and Europe is an advantage to underwriters. Commercial interests are the main buyers of satellite pre-launch insurance. Even though these commercial satellite owners prefer to use tried and tested technology, they often need to use the pioneering technology from NASA and ESA in order to deliver the new specifications demanded by end-users.

In many instances, if NASA develops a new piece of technology, such as a prototype, it will be tried and tested before NASA passes it on to industry. Thus, by the time underwriters are insuring the satellite (ie, when it is at the commercial interest's risk), in most circumstances, it is no longer a trial product. The flow of experience, expertise and technology from public to private interests therefore reduces the risks inherent in insuring satellites that could have elements of "prototype" in their design.

So, one of the main factors supporting the statement that technological advances reduce risk is the expertise and experience that result from the application of scientific progress. It is true that the satellite industry is still a business in its infancy, yet as the industry and technology develops, knowledge and wisdom are gained. This applies in both the public and private sectors. This know-how enables improvements in loss prevention and risk management. As the industry learns from past mistakes and incorporates this knowledge into its innovations, satellite underwriters are less at risk.

It is not just the fact that technological experience and expertise are developed over time that reduces risk to underwriters, but also that technology is being developed internationally. Scientific progress in satellites is truly global. For example, ESA explains that the XMM–Newton Satellite comprises components and scientific instruments from 14 different countries. Further, ESA asserts that "Designing and making ESA's greatest engineering challenge to date has involved universities and companies all over Europe"[iv].

This international effort to improve technology suggests a wealth of global talent driving the satellite industry. Included in these activities are the assembly, testing, transit and launch of the satellite. The pioneering and international character of those employed in the satellite industry is a clear example of how technological advances reduce risk to underwriters. I will now offer specific examples to support the statement.

Assembly

A satellite is not "manufactured" in the usual sense. It comprises of a number of sub-systems, themselves made up of components, which need to be assembled to create the finished product. Underwriters are on risk whilst the satellite is being assembled.

A key factor reducing risk for pre-launch insurers lies in the objectives of the satellite manufacturers. They want to deliver their satellite to the specified standard on time. The manufacturers' reputation for quality and reliability is paramount. In order to ensure they perform the requirements of the contract, satellite manufacturers invest heavily in risk management. The method in which a satellite is assembled is an excellent example of the level of risk management adopted.

At assembly, there is a team of mechanical ground support engineers whose sole task it is to move the satellites to the required position. Then, the engineers assembling the satellite refer to a procedures manual for every operation performed. They are painstakingly accurate in their work. A recent risk survey of a satellite manufacturer explained that: "Procedures for mounting and securing of satellites in frames … are produced and there is a documented quality control function to their implementation. At each station the AIT procedures documents {assembly integration and testing} were present and actively referred to" .

Technology assists the engineers, enabling them to work in this meticulous fashion. Each satellite is assembled on a hi-tech "dolly". The dolly is usually purchased from a specialist manufacturer and is often self-propelled. This equipment ensures that the satellite can be delicately assembled in an environment of controlled certainty. (It should be noted, however, that the risk of human error can never be entirely eliminated during assembly. There is always the danger of a dropped spanner or a misplaced rag, which could result in a loss.)

Testing

Of the time 'on risk' during a pre-launch policy, 60% is while the satellite is being tested. This is to make sure it will perform properly in space. The satellite is tested in atmospheric conditions that replicate space (this is known in the industry as "shake, rattle and roll"!) Acoustic, mechanical, electrical and environmental tests are all applied to the satellite. Pre-launch underwriters cover the satellite for physical loss or damage during testing. They do not cover faulty design that might come to light during testing.

Testing is the most hazardous stage of the risk. It is when the satellite is being operated on by external forces. Loss statistics support this assumption. Fortunately, there are a number of positive arguments that support the notion that technological advances reduce risks associated with testing.

Scientific progression has enabled testing to operate in a very controlled environment. A recent risk management survey explained how simulations are performed, using monitoring equipment preset to levels that ensure that external forces cannot damage the satellite: "For each system requiring simulation a separate power supply is provided...fitted with voltage and current monitors that can be preset to desired reaction variables from the norm. The typical practice would be only to allow for current/voltage variances within the tolerances band for the item that is being powered"[vi].

If tolerance bands were incorrectly overstated, due to human error or a technical failure, there are further safeguards in place: "Power is fed...from a continuously managed source with current and voltage monitors which can trip in an overload scenario"[vii].

These are direct examples of how technology reduces risk during testing. Even more advanced technology means that some elements of testing on the satellite can be avoided. This is where replicated dummies are used or where "Physical testing is replaced by modelling and analysis"[viii]. These methods minimise risk to the satellite by using duplicates and models to carry out certain stages of testing.

A final example of how technology reduces risk during testing, but this time indirectly, is provided by information from a recent risk management survey: "An interesting concept for the acoustic tests chamber was that the vertical mechanical vibration test platform is mounted in the chamber. Thus, after the acoustic test, and without additional movement, this mechanical test can be performed"[ix].

In this instance, scientific know-how is combined with basic common sense to reduce risk. As technology advances and manufacturers gain experience, simple yet fundamental risk management improvements are introduced. Here, it meant constructing the facilities to enable the satellite to stay in one place during two sets of testing.

Storage

There are definite ways in which technological advances can reduce risk when the satellite is being physically handled during assembly, testing and transit. Yet, where pre-transit storage is concerned technological advances deliver less benefit to underwriters. This is particularly true concerning protection against natural perils like earthquake or windstorm.

Three of the big five satellite manufacturers have their largest operations in California. They implement expensive loss prevention techniques in order to reduce the impact of an earthquake. Yet current technology makes it impossible to protect buildings entirely from such damage. Recent research undertaken at New York University, however, has developed revolutionary construction design by means of sphere/impact technology. These developments could radically reduce earthquake damage to property in the future.

There is one clear example of how technology can lessen risk of damage to the satellite whilst being stored. This is by using technology to control atmospheric conditions. Satellites are sensitive to dust, heat and humidity. They are constructed of thousands of wires and circuits all susceptible to malfunction if stored under the wrong conditions. Technology facilitates the use of equipment to monitor the correct atmospheric conditions in "clean rooms" while the satellite is being stored: "Whatever the class of clean room or designated area, temperature and humidity is constantly monitored"[x].

Transit

A satellite can be transported by air, sea, road or rail. In some cases, all of these methods will be used to get the satellite to final destination. While testing is arguably the riskiest element of a pre-launch policy, satellites are highly susceptible to damage during transit. Yet, although claims figures show that most satellite losses occur during transit, they are almost always very small, incidental claims such as handling damage to minor components. Such losses do not adversely affect the pre-launch loss ratios in any meaningful way due to the low value of these claims against premium. Also, sensible deductibles are included on most pre-launch policies which cater for these smaller losses.

Technological advances reduce risk during transit. Scientific progress enables satellites to be transported in custom-designed containers, with their own power, air-conditioning and shock readings. The container is self-sufficient in its ability to protect the satellite. It can monitor temperature and humidity levels while in transit so that the satellite has the same treatment in the container as it does in the clean room.

High-tech monitoring is useful, but simple, unscientific risk management factors should not be overlooked. Route studies during road transits can reduce risk. Something as basic as verifying bridge clearance can mean the difference between a successful or bungled transit.

Specialist sub-contractors are used for transporting satellites. These specialists have embraced technology in their particular area of expertise. This further reduces risk. One such company explains: "As technology moved so did the specialised shipping and moving requirements of these industries. XYZ was there to help pioneer some

of these specialised requirements and will continue to provide the advanced requirements needed"[xi].

Technological advances also reduce risks during sea transits. Arianespace, the European manufacturer of the Ariane 4 and Ariane 5 launch vehicles, has two custom-made vessels. "MN Ariana" is designed for Ariane 4 and "MN Toucan" for Ariane 5. Arianespace explains how it has used the application of practical sciences to reduce risk during sea transits: "MN Toucan has been specially built to transport the components of Ariane 5 from Europe to Guiana...it has a reduced draught to reach the port of Kourou, whatever the tide... Its special safety features include 2 motors, 2 propellers, 2 propeller shafts, 2 stem propellers ..."[xii].

One final example of how technology has reduced risk during transit is in terms of packaging. Many satellites are manufactured for defence purposes; the end-user could be a client such as the US government. The defence departments of national governments have very stringent regulations for the packaging and transportation of their satellites. One major satellite manufacturer states their packaging standards as "Military standard 2073"[xiii]. Such corporations will also employ package design engineers who use the latest technology to ensure their cargo is transported safely.

Launch

While testing and transit are particularly risky elements of pre-launch coverage (a fact supported by the loss statistics), many underwriters believe that the potential for loss or damage to the satellite is greatest when it is on the launch pad, after integration with the launch vehicle. This is understandable, particularly when bearing in mind that the pre-launch satellite risk finally terminates during the launch, at 'the point of no return' (See Appendix 1: Satellite pre-launch insurance).

There is indeed the danger of the satellite blowing up in the event of a failed launch at the point of no return. However, there has never been a satellite loss at this crucial stage. There has been a loss for damage to the satellite prior to launch and during integration with the launch vehicle, but this was due to a heavy-handed crane manoeuvre rather than a highly technical electrical or mechanical failure blowing up the satellite.

Technological advances during the launch attempt reduce risk to underwriters. This argument is evidenced by loss statistics provided by the launch market. These statistics reveal that as space technology has progressed, there have been fewer losses during the launch stage of the risk compared to the in-orbit phase.

From 1990 to 1995 launch flight losses made up 75% of claims to the space market. By 1996 to 2001 launch flight losses accounted for only 39% of space claims, the remainder being in-orbit losses.[xiv] Although pre-launch insurers do not cover either of these losses, it is a positive trend that fewer incidents are occurring during the launch phase, just after the point of no return. It implies that technology, experience and risk management have reduced this risk during launch.

Looking at the Arianespace launch campaign further enhances this argument. The new technology developed for the Ariane 5 launch campaign affords opportunity for numerous tests, checks and re-tests even within the final hours, minutes and seconds of launch. These tests have been developed further since the spectacular launch failure of the maiden flight in 1996 when Ariane 5 exploded in mid-air 37 seconds after lift-off. This failure was blamed on faulty computer software in the rocket's guidance system. Since this explosion, Arianespace have gone to great lengths to ensure that meticulous checking and back-up procedures support technology.

Examples of the checks that take place from the start to end of the Ariane 5 launch campaign include: "Technical evaluation of the state of ground installations, procedures and software, check on correct firing, check on generator ignition, check on programming of chains, check on shut-off of the ground safety system"[xv].

Further: "If one of the checks carried out by the on-board computer during the ignition phase is negative... it interrupts the ignition phase and carries out a stop sequence"[xvi].

All the procedures used during the launch combine basic risk management with the use of high-level technology to ensure risk is kept to a minimum.

To conclude this section, the specific examples cited along with the general comments, all firmly support the assertion that technological advances reduce risk to underwriters. Now to the counter-arguments.

Technological advances increase risk to underwriters

As with the previous section, I will begin with a general discussion of how technological advances can increase rather than reduce risk to underwriters. This will be followed by specific examples.

Commercial buyers of communication satellites primarily drive technological advances in the satellite industry. Today, these satellite operators require more satellites, with longer lifetimes, at cheaper costs and in a shorter time-span. The demand for more satellites is met by a faster rate of production and launches. Increased

specifications are delivered by new technology. The race for a greater quality and quantity of product within shorter time frames implies that costs and deadlines are reduced at the expense of stringent risk management.

A recent analysis by a London broker of trends in satellite technology suggests that, as technology increases, so does risk. The analysis describes satellite technology in the past as "relatively stable" with "long lead times for design and production" and "long gaps between launches". It contrasts these practices with those today, which are characterised by "Shorter lead times", "increased production and launch frequency" and "increased use of new technology"[xvii].

As technology advances, manufacturing and testing times are reduced and launches are much closer together. This implies the process is being hurried with unnecessary risks taken to ensure deadlines are met.

If this is a true reflection of the current state of the satellite industry, then pre-launch underwriters should be concerned. It is clear that manufacturers and buyers are competing in a race for cheaper but better products, so there must be implications for risk management practices during pre-launch. For instance, is a manufacturer chosen because of his good record or because he is the cheapest? Are the same cost-driven choices made for the launch vehicle and launch site?

To understand if stringent risk management is being eschewed in favour of cheaper, quicker production, it is important to determine the reasons why a customer chooses a particular manufacturer. This reveals that it is not in the manufacturers' interest to abandon quality risk management in order to save a few million dollars.

A satellite operator will choose a manufacturer depending on two key factors. The first is a manufacturer's past record in building satellites of a similar specification and those satellites' in-orbit performance. The second factor is the schedule, the time it takes to get the satellite built, tested and launched. These two criteria can conflict. To ensure the satellite will perform in space, the manufacturer must spend much time, effort and money testing it. To ensure the schedule is attractive to the client, the manufacturer has to keep the timetable as short as possible. The manufacturer may have to reduce the schedule by limiting the amount of time spent testing the satellite.

Overall, because there are so many millions of dollars at stake, it is simply not worthwhile for the manufacturer to take unnecessary risks. In cutting corners he might save a few million dollars prior to launch. These cost-savings will be negligible compared to the risk of an in-orbit failure, due to lack of testing, which will cost many millions of dollars to correct. Depending on the terms of the contract, the manufacturer might not be liable for these costs; even so, its reputation will be severely damaged.

Despite this, underwriters should be aware that, to meet ever-tighter schedules, the amount of testing on each component, at each stage of assembly and integration, is significantly reduced today. Yet this does not significantly increase risk to underwriters at the pre-launch stage, as it is more likely that any result of inadequate testing would occur in orbit. Also, as in-orbit performance is the other main criterion upon which manufacturers are judged, it is likely that, although less testing takes place, it is sufficient. Finally, and perhaps most obviously, as less testing takes place, underwriters are exposed to this risk for a shorter period of time.

So technological advances that drive forward competition and economic performance do not greatly increase risk to pre-launch underwriters. Scientific progress can, though, increase risk in respect of greater values insured and more exposure to physical damage.

Operators are demanding longer lifetimes, greater capacity and diversity of applications from their satellites. New technology meets these specifications by increasing size, weight and complexity of design of satellites. All of these technological enhancements increase risk to underwriters.

The BSS-702 is a new satellite developed by Boeing in 1999 for Internet services and digital radio. The size, complexity of design and value of the 702 all greatly exceed those of earlier products such as the BSS-376. The 702 is approximately 40 meters wide when deployed and weighs 2950 Kg. In comparison, the satellites in the 376 range measure approximately 7 meters wide when deployed and weigh approximately 800 Kg. As satellites get bigger so do the launchers that put them into orbit. Ariane 5 can carry up to 6,800 KG, 50% more than Ariane 4.

As size, weight and capacity increase, so do the values at risk. A satellite today is worth up to $120million and a launcher $140million. These increased values enhance underwriters' exposure. This should not be of concern though, as on 'rated policies' and also 'revenue-based flat premiums', underwriters are receiving the commensurate premium for values at risk. Yet pre-launch insurers should make sure that current deductibles remain sufficient for values in the future. At today's values, deductibles adequately cover attritional losses. However, as satellites become bigger and components more expensive, underwriters could find themselves more exposed to a partial loss if these deductibles are not increased in line with the higher values.

Underwriters could also be more at risk of physical damage due to the increased complexity of design of satellites. The BSS-376 used older, simpler, "spin-stabilized" technology. This meant that the solar panels powering the satellite were displayed on the outside of a spinning telescopic cylinder. The new 702 uses large solar panels that are attached to the satellite and deployed once in space. These panels are very light, fragile and somewhat unwieldy, as they have to be folded away prior to deployment during the pre-launch stages. There have been pre-launch physical damage losses during handling of these very delicate structures. Before the technology was available to use this type of deployable, solar panel underwriters would not have been exposed to these losses.

Satellites are manufactured to the specification of each buyer and so each one could have some element of new technology within its design. As mentioned earlier, even though satellite owners like basic technology in their satellites, market demand for bigger and better products often requires the introduction of new technology. Thus, to a lesser or greater extent, insuring satellites can be something of an uncharted territory. This enhanced risk is driven by new technology.

Remember that the relationship between government agencies and commercial interests can reduce this risk. This is because much of the prototype technology in satellites is tested and used by governments and then passed on to commercial operations at a later date.

As regards military technology, it can take up to 10 years before "new" innovations are passed over to commercial interests by the government. However, this is not always the case. Sometimes government agencies complete only the research, passing their ideas on, in their prototype stages, to a commercial entity. In these instances, the commercial satellite manufacturer will build and test these "ideas" on behalf of the government agencies. If the new technology reaches the commercial operations at this stage, then the risk of handling this technology lies firmly with the commercial entity and their insurers. In these instances, underwriters gain no benefit.

One final, general point to note on the way technology increases risk concerns the nature of the commercial satellite industry. Because the industry is a fast moving, competitive market, there has been constant merger and acquisition activity. In the short term, mergers and acquisitions often impact negatively on risk management and quality control. Managers are charged with bringing together two entities in a seamless fashion, while often competing for their own position. Such an environment, even if only temporary, is not conducive to reducing risk.

The current demands of customers and the way that the satellite industry reacts to these demands supports the statement that technological advances increase risk to underwriters. Specific examples will now follow supporting this argument.

Testing

As noted, testing times have sometimes been reduced in the race for shorter scheduling times, but this does not significantly increase risk to underwriters. While we have reviewed a number of examples of how technological advances reduce risks during testing, loss statistics and anecdotal evidence reveal that testing remains very hazardous and that technological advances can increase this risk.

Because there are so many new innovations in satellite technology and in the equipment used to test the satellites, there is greater exposure to a loss of this hi-tech kit. This is evidenced by a recent loss during testing by NASA: "A $75m NASA satellite was badly damaged during a botched pre-flight test.... An equipment function or software glitch probably caused the mishap.....whilst undergoing a vibration test"[xviii].

As technology improves, components become more specialised and are sourced from new suppliers. Lack of knowledge and experience in using these new components during testing has led to losses. A recent claim advised to underwriters by a commercial satellite company was as a result of exactly this scenario. Because the engineers testing the satellite had never before used a critical piece of testing equipment, they were not aware of its specific qualities under vacuum conditions. Because of this the equipment malfunctioned and resulted in a large claim.

A final point to make regarding testing is that, as technology advances and the testing equipment gets ever more complex, there is a real danger of the little, but crucial, factors getting overlooked. Further anecdotal evidence confirms this. An example of one such loss was when a satellite, being tested by a team on a Friday, was unscrewed from its dolly and turned vertically. The satellite was left in this position over the weekend. On Monday morning a new team came in to continue working on the satellite. Assuming it was still screwed to the dolly, the team turned the satellite 90 degrees to test a different section. Of course, the satellite fell off the dolly resulting in a claim to underwriters.

Storage

Storage is a considerable risk for pre-launch insurers and there have been a number of large losses while satellites were being stored. The primary reason for this enhanced risk, as noted before, is that the main locations of three

of the "big five" satellite manufacturers are based in California, as is the Vandenberg Launch site. The great concern for underwriters is the aggregate exposure of satellites and launch vehicles in the event of an earthquake. Technology is used to reduce earthquake damage to property but it can also indirectly increase the storage risk. Technology has led to greater values exposed and the need for larger facilities to satisfy demand. One prominent satellite manufacturer with a $1billion turnover, employing over 3,000 people, describes its main operation in California as "two buildings, encompassing 1.3m square feet"[xix].

The risk of damage to the satellites in the event of an earthquake is obvious and the description above gives some indication of the amount at risk in California. A further exposure to natural perils is windstorm in Florida. The Cape Canaveral launch site is in Florida and underwriters are exposed to some pre-launch storage here.

A further issue concerning satellite pre-launch storage is the fire risk. In reality there is a very limited risk of a loss due to fire (except following an earthquake). This is because locations are highly controlled with sophisticated fire monitoring systems. Also, no propellant fuel or smoking is allowed in the assembly, testing and storage areas.

The technology used to monitor a fire hazard reduces risk to underwriters. Yet, in the event of damage to this monitoring equipment, the results could be disastrous. For example, if sprinkler pipes suffered structural damage and ruptured, or if there was a malfunction activating the entire wet-pipe sprinkler system, underwriters would not be faced with a fire loss but with hefty claims for wet damage.

One solution is for manufacturers to utilise dry-pipe sprinkler systems where a valve prevents water entering the pipe work to the sprinkler heads until that valve is activated. Some manufacturers use this system; underwriters are suggesting others do the same.

Transit

As satellite technology increases so does the technology used to transport the satellites. The decision by Arianespace to purchase a new vessel specifically designed for Ariane 5 is a good example of this. Thus it seems that technological advances do not increase risk during transportation. This is because the transport is modified in line with modifications to the satellite.

However, as satellite technology develops, more components are sourced externally. This means that there are more transits for components than in the past. This increases risk to underwriters if the policy attaches when the satellite manufacturer takes ownership of the components prior to arrival at his premises. Because these transits are not adding value in terms of revenue or final value of the satellite, it is unlikely that this increase will be reflected in the premium.

Launch

Technological advances increase risk to underwriters in a very real sense during integration with the launch vehicle and the launch attempt. This is due to the higher values exposed and the possibility of aggregations. Ariane 5 is twice as heavy and twice as powerful as Ariane 4; by 2005 it will carry payloads of up to 12 tonnes. The same order of increase applies to Boeing's upgrade of Delta 3 to Delta 4 launch vehicles. Ariane 4 and 5 can also carry double payloads. So on a double payload launch, pre-launch underwriters could be insuring two satellites as well as the Ariane launch vehicle.

A further risk enhancement at integration results from the increased frequency of launches today, compared to 5 to 10 years ago. When Ariane 4 was first launched in 1988, launches would have taken place every few months. In the last 10 years launches have been occurring monthly. This pace will continue and accelerate for Ariane 5. It implies that, as launch dates are crammed together, risk management in preparing for each pre-launch will be reduced.

However, the loss statistics do not support this assumption; in fact, they refute it. This is probably because, as launches become more frequent, the familiarity and experience gained reduces the risk. There is a concern, however, that if demand increases so much that the launch service providers experience back-logs, corners could be cut in order to catch up. Also, there could be an accumulation of satellites at the launch site, further increasing exposure to pre-launch underwriters.

Financial consequences

In the explanation of key terms (Appendix 1), it is noted that satellite pre-launch insurance can be extended to insure financial consequences coverage. These could be the loss of incentives, or financial penalties, which a satellite manufacturer or operator might incur due to physical loss or damage to the satellite causing a launch delay. A discussion concerning technological advances in respect of this coverage further supports the argument that technological advances increase risk. However, because financial consequences is a relatively new area of pre-launch insurance and therefore an extension to this debate, this argument appears in Appendix 2, which should be read alongside the main text.

Appendix 3 contains a discussion of variations in risk associated with the major launch vehicles, launch sites

and manufacturers. This is an acknowledgment of the significance of this subject to a complete risk assessment of satellite pre-launch insurance. Although it does not directly argue for or against the statement in the title, by reading this appendix prior to the conclusion, the reader will have a more comprehensive understanding of the relationship between technological advances and satellite pre-launch insurance.

Conclusion

Do technological advances reduce risk? Bringing all the evidence together it seems that, on balance, yes, technological advances do reduce risk to underwriters.

The strongest argument to support this is the wealth of experience and expertise gained during 40 years of scientific progress within the satellite industry. Lessons are learned from mistakes and this know-how is channelled into high-quality risk management and loss prevention. Specific examples, illustrating how technological advances reduce risk at each stage of the pre-launch, give further credence to the assertion.

However, technological advances are a double-edged sword for underwriters. As the Chairman of one prominent satellite manufacturer says: "Our industry is a marriage of cold logic and passion"[xx].

The many benefits bestowed on underwriters by scientific progress, such as technical expertise or "cold logic", are partly offset by the increased risk attributed to the "passion". This passion is the innovation, improvement and competitive edge driven by technological advances and demanded of manufacturers by the end-users of satellite technology.

There is increased risk to underwriters resulting from the drive for technological advance. Greater values are at risk and there is more exposure to physical damage due to complex satellite designs. Furthermore, reduction in scheduling times enhances the risk of a claim for financial consequences coverage (See Appendix 2).

Overall, then, technological advances reduce risk more than they increase it and this is likely to hold true in the future. As the satellite industry continues to grow, the "cold logic" and "passion" will also develop, leading to more competition and innovation offset by further experience and expertise.

Yet, there are instances when technological advances make little difference. When assessing the quality of launch sites and launch vehicles, although Russia is less technologically advanced than the western world, the level of risk is the same (See Appendix 3). Further, there is no difference in the level of technological advancement between the commercial satellite manufacturers; they are all of an industry standard. So here, too, the risk is equal (Appendix 3).

So if, on balance, technological advances reduce risk for underwriters, should the level of rating be adjusted accordingly? As an underwriter, of course, I would say no. Regardless of the level of technological advancement, satellite pre-launch insurance is a risky business. Underwriters are insuring high value, highly-sensitive products. Coverage is provided from the beginning of the satellite's existence until it is finally blasted into space.

Satellite pre-launch insurance is profitable business but the assured buys this coverage for a reason. Although pre-launch underwriters have never had a total loss on their pre-launch account, it might happen one day. If it does, there needs to be a good size fund to pay the claim. So in spite of the conclusion that, "yes", technological advances do reduce risk to underwriters, the rates should not be reduced. In fact, because of the recent catastrophic events affecting the global insurance and reinsurance markets and the soft market conditions of the late 1990s, it is fair to argue that rates should still be going up!

Appendix 1

Explanation of key terms

"Satellite"

The dictionary definition of "satellite" is a "celestial body orbiting another of a larger size; a manufactured object or vehicle intended to orbit the earth, the moon or another celestial body"[xxi]. The Soviet Union launched the first man-made satellite, Sputnik 1, in 1957. Sputnik formed part of the USSR's space research programme. Today satellites are designed for various uses such as observation, navigation and communication.

The definition of a satellite within the context of an insurance policy is broader than the dictionary definition. A typical description under the "Interest" section might read...

"Satellites and/or payloads and/or instruments and/or vehicle equipment bays including components and parts and ground segments and ground support equipment and propellant shipped as part of an individual project[xxii]".

This definition of the assured's "interest" is often extended to include launch vehicles. These are expendable rockets that transport satellites into space. The Interest section could also cover, for consequential loss, launch site facilities, launch pad and manufacturing premises. This encompasses far more than "manufactured object or vehicle intended to orbit the earth". It illustrates how satellite insurance embraces a

great deal more than merely insuring the "satellite" according to its purest definition.

In this dissertation when I refer to technological advances in relation to a "satellite", the term is used in a very general sense. So, depending on the context, I might be referring to the entire "satellite" industry, which encompasses launch vehicle manufacturers, launch service providers and specialist component makers, for example. In the same way, when I discuss "satellite technology" this also includes technology used by those same launch vehicle manufacturers, launch service providers and specialist component makers, who are not actually building satellites but are inextricably linked to their manufacture.

"The Satellite Industry"

The satellite industry is comprised of satellite manufacturers, launch vehicle manufacturers and launch service providers. It also includes many small companies that make the component parts that will become the satellite. But who buys the satellites and what do they use them for?

The uses of satellites are observational, navigational and communicative. Satellites used for observation and navigation are often state-owned. Commercial interests generally own communication satellites.

The past 30 years have seen significant growth in demand for all satellites. Yet demand for communication satellites, for commercial interests, has been unprecedented. Commercial interests often buy satellite insurance, more so than national interests. National interests seldom buy insurance as they have a much lower financial risk compared to commercial interests.

Government agencies buy satellites for military and civil purposes. Satellites can track weather patterns or provide data necessary for military intelligence. Companies mostly buy satellites for communication purposes. Satellite operators purchase satellites to rent them out to other companies such as TV networks, telephone companies and Internet service providers. Alternatively, the satellite operators might be the end users themselves.

According to the latest available statistics[xxiii], $80 billion was generated by the global satellite industry in 2000; 65% of this comprised of commercial space revenues, the remaining 35% made up of civil or military satellite expenditure by governments. Although conclusive data is not available, it is likely that most of the 65% of commercial satellite revenue was insured for the satellite's pre-launch, launch and time spent in orbit.

Regarding the remaining 35% of satellite revenue, consisting of governments' expenditures, even if these satellites are not insured when they are at the government's risk, they are likely to be insured for pre-launch. This is because, at this stage, risk lies with the commercial manufacturers.

Therefore of the $80 billion expenditure, it is a fair assumption that most of it is insured. Half of the $80 billion is generated from satellite services, such as leasing the transponders. The risk of loss of this revenue is insured in the satellite life market. The remaining $40 billion is comprised of revenue from the manufacture of the satellites, and launch services (Appendix 1A + 1B). Much of this will be insured in the pre-launch market. These statistics demonstrate the worth of the satellite industry. As the number of launches is expected to increase significantly during the next decade, these values will also increase.

"Satellite Pre-Launch Insurance"

Satellite pre-launch insurance was developed in the mid 1980s. It was originally written by the non-marine property market. The property underwriters insured the buildings, business interruption and also transit and storage of the satellites prior to launch. The "Space" market insures the satellites during their launch (launch insurance) and while they are in orbit (life insurance).

As the non-marine market became conscious of what they were covering and at what rates, underwriters became uncomfortable with the pre-launch element of the risk. Pre-launch sat more easily in the London marine cargo market. The broker therefore placed the "pre-launch" part of the risk with cargo underwriters, drawing on their expertise in the worldwide transit and storage of goods. The cargo underwriters used their own conditions, clauses and rates for the pre-launch risk.

Satellite pre-launch insurance soon came to encompass more than transit and storage. Clients realised that if underwriters' risk attached at the time the satellite was transported to the launch site, then they, the client, were exposed during the all-important assembly, testing and integration stages. They also wanted to purchase insurance for any "extra expenses" they might incur in the event of physical loss or damage to their satellite. These expenses might include cost of overtime for key workers in repairing a part of the satellite, or the cost of re-transporting components for example. Cargo underwriters responded to this by offering an all-encompassing product.

"Pre-launch insurance" now covers all risks of physical loss or damage from the time the components (that will become the satellite), are at the assured's risk. Coverage continues while the satellite is assembled, integrated,

tested and while being transported to the launch site and integrated with the launch vehicle. "Pre-launch" coverage ceases at launch.

The definition of cessation varies; "intentional ignition of 1st stage engines", "release of clamps" and "ignition of solid rocket boosters" are a few examples. Although the definitions vary, the intention is the same. That is, for pre-launch underwriters to remain on risk until the "point of no return" during the launch. Risk then passes to the space underwriters.

Satellite pre-launch insurance can be extended to insure the financial consequences that a satellite manufacturer or operator might incur, due to physical loss or damage to the satellite causing a launch delay. These differ from "extra expenses". Financial consequences refer to financial penalties or loss of incentives. The exposures will depend on the terms of the contract between the satellite operator, manufacturer and launch services provider.

"Technological Advances"

The dictionary definition of "technology" is "the application of practical, mechanical sciences"[xxiv]. Therefore, "technological advances" is a reference to improvements in the application of practical and mechanical sciences.

"Technological advances" in the context of this dissertation refers to the progress in practical science, technology and information and how that progress affects the satellite at each stage of the pre-launch risk.

When discussing "technology" and "satellites" it is interesting to note that some of the equipment used inside the satellites is not cutting-edge technology at all. The components used are often the result of basic, tried-and-tested engineering. The reason for this is because the satellite owners do not want novel technology inside their satellites. They want something that they know will function correctly once in orbit. However, although they want tried-and-tested technology, it can be necessary to use new technology in order to deliver market demands of even bigger and better products. The technology used to assemble, test and store these components, and to get them into space is also at the forefront of scientific progress.

"Risk"

"Risk" to insurers is the possibility of financial loss arising from a claim, following a peril covered under an insurance policy. "Risk" to satellite pre-launch insurers encompasses a myriad of issues.

When deciding whether to insure a satellite for its pre-launch exposure, the underwriter will assess the risk. Coverage issues are key in establishing how exposed the insured interest will be to a potential loss. The underwriter will look at attachment and termination of risk and what coverage is being offered in between.

One of the most important considerations will be how much premium the underwriter should charge to adequately reflect the exposure. In assessing the risk and the premium to charge for it, underwriters will draw on their previous experience of this type of business.

In writing a satellite pre-launch policy, the underwriter could be at risk during assembly, test, transit, storage, final integration and launch. Risk will vary according to the breadth of coverage offered. Most satellite pre-launch policies are constructed around the coverage offered by the Institute Cargo Clauses A (ICCA) or the American equivalent. These clauses cover all risks of physical loss or damage to the satellite subject to standard exclusions (Appendix 1C). If the insurance is extended to include financial consequences coverage, the "risk" increases significantly and so should be reflected in the rating.

The meaning of risk to satellite pre-launch insurers varies according to the coverage and duration of the policy.

Appendix 1A

The "Big Five"commercial satellite manufacturers

These manufacturers are insured in the London satellite pre-launch market.

Boeing Satellite Systems (BSS)	USA
Space System Loral (SS/L)	USA
Lockheed Martin (LM)	USA
Alcatel Space	France
Astrium Space	France, UK

NB. There are other satellite manufacturers but they are far less significant in terms of market share as they are not very active in the commercial space market. They are more likely to produce satellites for specialised scientific purposes or domestic programmes only. These include Russian, US, UK, Japanese and Chinese companies.

Appendix 1B

The "Big Four"Commercial launch vehicle manufacturers and the major commercial launch vehicle systems

Arianespace (EU)

Launches from Kourou, French Guiana. Located north coast of South America. Near to the Equator.

Maiden Flights: Ariane 1. 1979
Ariane 4. 1988
Ariane 5. 1999

Brief History: The Ariane Programme began in 1979, only

8 of 141 missions have ended in failure. Ariane 4 is being phased out in favour of Ariane 5. The first Ariane 5 exploded in 1996 on its maiden flight. Ariane 5 has had 8 out of 9 successful test launches to date.

Boeing Delta (USA)
Launches from Cape Canaveral, Florida and Vandenberg Airbase, California.

Maiden Flights: Delta. 1960
Delta II. 1989
Delta III. 1998
Delta IV. Expected 2002

Brief History: Delta II originates from Thor , which was the very first Delta launch vehicle. Since the first delta flight in 1960, 215 out of 227 flights have been successful. Delta III was an upgrade of Delta II. It is being replaced by Delta IV.

Sea Launch (USA {Boeing}, Russia {Energia}, Norway {Kvaerner}, Ukraine {Yuzmash})

Satellites are transported from California to a floating platform in the Pacific, positioned on the Equator.

Maiden Flight : Zenit. 1999

Brief History: Began in 1999. There have been 6 successful launches and 1 failure to date.

International Launch Services (USA {Lockheed} Russia {Khrunichev and RSC Energia})

Launches from the USA and the Baikonur cosmodrome in Kazakhstan.

Maiden Flights: Atlas. 1957
Atlas I & II. 1990 & 1991
Atlas V. Expected 2002
Proton K. 1965
Proton M. 2001

Brief History: There have been 850 shared flights between Atlas and Proton. Proton has 96% reliability. Atlas II and III have 100% reliability.

NB. There are other smaller launch vehicles used for smaller payloads but these are not significant in the commercial space market. Japan, Israel, and India all have launch vehicle manufacturing capabilities. The NASA Space Shuttle is also used for launching satellites, but non-commercial observation and military satellites.

(Statistics as at 01/06/01. Please refer to main text for sources)

Appendix 1C

Typical exclusions in a satellite pre-launch policy

- Mechanical deficiencies
- Error, omission or deficiency in design
- Wear, tear or gradual deterioration
- War or war-like actions
- Terrorism
- Confiscation by government or public authority
- Insolvency or financial default.

NB These are merely examples. A policy can be constructed to add further exclusions or to include some of the perils excluded above. The extent of coverage is entirely dependent on the needs of the client and what the underwriter is prepared to offer.

Appendix 2

Technological advances increase risk to underwriters: Extension of discussion to include financial consequences/extra expenses coverage

Satellite pre-launch insurance can be extended to insure any financial consequences that a satellite manufacturer or operator might incur due to physical loss or damage to the satellite causing a launch delay. They can include financial penalties, or loss of incentives.

Financial consequences vary depending on who the insured is and what their contractual obligations are to the other parties involved. If the insured is the manufacturer, exposure might be loss of incentives from, or financial penalties to, the satellite operator for failing to deliver the satellite on time. Incentive payments can be up to $150,000 per day.

If the insured is the satellite operator, the consequences of a delayed launch could be the financial penalties payable to the lessees who have contracted to use the satellite in orbit by a certain date. Alternatively, the loss might be the shortfall in the operator's own income that would have been generated by using the satellite by a particular date.

When covering financial consequences, pre-launch insurers will only pay a financial consequences claim if a launch delay has occurred due to a physical loss or damage to the satellite. The coverage provided is often on a "named perils" basis. This means the insurer will respond only if there is physical loss or damage to the satellite as a result of the perils named in the policy. These named perils could be "fire, flood, earthquake and windstorm", for example. Alternatively, the policy could be on "all risks" basis with general exclusions.

A policy could also cover delay due to physical loss or damage to the manufacturer's premises, launch vehicle, ground support equipment, and other launch site facilities. It could also indemnify the insured for the extra expenses incurred as a result of a delayed launch, such as the costs of re-testing.

Technological advances greatly increase the risk of a financial consequences claim. The reasons are twofold. First, customers are demanding more advanced technology from their TV, Internet, and mobile phones. This, in turn, means that satellite operators are demanding bigger and better satellites, in much shorter time frames, from the manufacturers. Satellite manufacturers are responding to these demands by reducing testing times and negotiating schedules that are difficult to meet.

This means there is little or no time-buffer to underwriters in the event of a physical loss or damage claim. Such a loss will immediately affect the schedule resulting in a financial consequences claim. This is compounded by the fact that launch dates are now very close together. In the event that a satellite misses its launch date, another slot will not be available for some time. In the past a slot would have been more readily obtainable

Secondly, because the manufacturers' schedules are so tight, any seemingly insignificant piece of damage to the satellite could result in a financial consequences claim. This is because there could be lengthy replacement times for parts that are so technologically advanced. Such parts might be specifically made to order and will have to be painstakingly re-tested and re-integrated into the satellite. If there is even a short delay in the transit, due to a tiny physical loss or damage claim, the launch slot could be missed and a daily indemnity payment comes in to force. The best way to address all of these issues is to include a healthy daily deductible, or co-insurance, as a buffer, or to provide only very limited coverage on a named perils basis.

One final comment on financial consequences coverage, although not directly related to technological advances, is that such claims are very difficult to prove. This is problematic for both insurer and insured. For example, at the launch date, if the satellite is not ready, the manufacturer has to prove the delay was caused by a physical loss or damage to a particular component, by a named peril under the policy. In reality, launch delays occur for more than one reason such as problems with the launch vehicle, launch site and/or design faults during testing. Financial consequences claims usually involve some form of negotiated settlement between the insured and insurer.

Appendix 3

Quality of launch vehicles and launch sites

For the purpose of this discussion, "quality" refers to how technologically-advanced a launch vehicle or launch site is, how well it is risk-managed and, most importantly, its launch rate success. The generally held belief of underwriters is that launch vehicles and launch sites do vary in quality.

The quality of both the launch site and launch vehicle is crucial to the satellite's well being during the final stage of the pre-launch risk. The satellite will be stored and tested for approximately one month at the launch site, prior to launch and pre-launch insurers are on risk until the point of no return during the launch. So the satellite risk is inextricably linked to the performance of the launch vehicle, being the expendable rocket that transports the satellite into space. (Underwriters might also be insuring the launch vehicle under a separate policy.)

Appendix 1B lists the main launch vehicle systems and launch sites. Launch vehicle operators tend to use the same site for each launch. An Ariane rocket will launch from French Guiana, a Proton from Baikonur and a Delta or Atlas from Cape Canaveral or Vandenberg. A Zenit rocket is always used for Sea Launch.

Arianespace is one of the market leaders in the launch of commercial satellites. The Ariane programme began in 1979, only 8 of 141 missions have ended in failure[xxv]. The old workhorse, Ariane 4 is being phased out in favour of the upgraded Ariane 5. Ariane 5 has had 8 out of 9 successful launches to date[xxvi].

The United States is the other main player in commercial launch services. Boeing and Lockheed Martin launch from Cape Canaveral in Florida or Vandenburg in California. Boeing's Delta Launch vehicles are tried and tested for commercial and military launches with 215 successful launches out of 227 since 1960[xxvii].

The most cost-effective place to launch a satellite is near the Equator. It is from this point that the rocket uses the least fuel and enables better delivery accuracy. To take advantage of this, an international consortium established the Sea Launch Company in 1999. Sea Launch is a converted floating rig located in the Pacific on the Equator. It has had six successful launches and one failure to date[xxviii].

Russia and the former USSR are the other major launch service providers. The launch site at Baikonur, Kazakhstan is used more for military rather than commercial launches. Lockheed Martin (USA) and Krunichev and RSC Energia (Russia) own International

Launch Services (ILS). ILS launches from US sites and the Baikonur cosmodrome in Kazakhstan. Jointly, these companies have achieved more than 850 successful flights, since the 1960s[xxix].

The NASA Space Shuttle is also used for launching satellites. The shuttle is more than just a "disposable" rocket. It is an airplane that orbits the earth, with expendable rocket boosters attached. The airplane lands back on earth on mission completion. The shuttle has completed 106 missions since 1981. It is used predominantly for manned space flights and for launching non-commercial observation and military satellites. It is rarely used for commercial launches.

China, Japan, India and Israel all have launch sites but are not yet major players in the commercial market.

Launch failure statistics are very difficult to obtain, though some are provided above, as at June 2001 (please refer to bibliography for sources). They are at best patchy and quickly out of date. Despite this, it is possible to argue that there is very little difference in "quality" between launch sites in the USA, Kazakhstan, French Guiana or even China. This is contrary to the view of most pre-launch underwriters. They would price a satellite launched from Kazakhstan at a higher rate than a launch from the USA. This is misconceived for the following reasons.

First, when comparing a launch site in the USA to one in Russia, it is important to realise that the two countries have completely different conceptual beliefs on how to build and launch a satellite. The Russians use very sturdy, basic, tried-and-tested materials and engineering practices. They want their satellites to be launched effectively, to work and to last. The Americans use the newest designs, the most expensive materials and have a meticulous "kid-glove" approach in manufacturing and launching their satellites.

This is not to say one method is better than the other, or more or less risky – just different. Yet, because of these different approaches, commercial owners prefer to launch from the US or French Guiana. They like the "kid-glove" approach. Military satellites are more likely to be launched from Russia. This is evidenced by the joint venture by Russia and the USA, in the form of International Launch Services. Although there is some overlap, the Russian launch sites are often used to launch military Russian satellites with more of the commercial launches taking place in the USA.

Secondly, the choice of launch site is not so significant because, wherever it is, the manufacturer will have their own team, equipment and testing facilities. The manufacturer's base at the launch site will be a microcosm of the facilities at their own premises. It is important that the manufacturer and owner have adequately investigated the facilities available at the launch site prior to launch. They need to be aware of each stage of the satellite's transit and ensure compatibility with the launch vehicle. It does not really matter if the launch site is in China, Russia, India or the USA. As long as the manufacturer and client have done their homework and have all their equipment in place, the risk and so the rate should be the same anywhere in the world.

In fact, if there should be a differential in pricing, rates should actually be loaded for the launch sites in the USA. This is because of the exposure to natural perils in Florida and California. Remember, satellites are stored and tested at the launch site for at least one month prior to launch.

Quality of satellite manufacturers

If the success of a launch is dependent not on the launch vehicle or launch site but on the preparedness of the manufacturer who chose that site, it is important to consider the differences in quality among manufacturers.

The five major commercial satellite manufacturers are from the USA and Europe (see Appendix 1A). They dominate the market and have an "industry standard" level of technological advance and risk management. Because of the nature of their business, one manufacturer cannot be seen to be less sophisticated in their operations than another.

The manufacture of non-commercial satellites for non-commercial buyers, particularly for military satellites, is dominated by Russia, which controls approximately half of all production. The main Russian satellite manufacturers were formerly government-owned industries. They are now private enterprises yet still have very strong links with the state.

As noted above, the Russians have a completely different method of building and launching their satellites. They are less sophisticated than their western counterparts in terms of the equipment, materials and facilities they use. They are less technologically-advanced. Yet, although their methods are different, they have not been any less successful in manufacturing and launching satellites. Their results to pre-launch underwriters are no better or worse than their competitors in the west.

Here, then, is an instance where technological advances do not seem to reduce risk to underwriters. Russia does not need to be as technologically advanced as the USA and Europe, in order to achieve the same level of success. The reason for this is that Russia is delivering a different

product - basic, sturdy, 'built-to-last' military satellites. This contrasts to the western manufacturers who are developing state-of-the-art communication satellites for commercial interests. The level of technological advance necessary to successfully manufacture and launch satellites will vary according to the type of satellite being built.

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