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Satellite Power System (SPS) Initial Insurance Evaluation

September 1980

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Prepared for:

U.S. Department of Energy
Office of Energy Research
Satellite Power System Project Division

Under Contract No. AC01-77ET21059

DOE/NASA
Satellite Power System
Concept Development
and
Evaluation Program

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EXECUTIVE SUMMARY

The SPS concept, as currently conceptualized, poses many exposures to both financial loss and liability to third parties. In order to eliminate or minimize these exposures it is possible that insurance could be provided to protect certain risks during both pre-operational and operational phases. The international underwriting community has already shown a willingness to insure the sizeable risks affiliated with today's telecommunications satellites, and this precedent could serve as a basis for their acceptance of SPS ground and space-related exposures.

The major risks affiliated with the program stem from both the sizeable financial losses that could be incurred and the enormous liability exposures presented by extensive launch and space construction activities. The possible environmental effects of both the ground and space segments also present a substantial degree of risk. The interrelation of so many participants combined with the need for a continuous flow of resources into space and to launch and rectenna construction sites forms a dynamic system that can be severely damaged by catastrophic loss at a number of key points. The effects of the overall SPS effort, moreover, will extend into an international realm that today does not provide for the sharing of liability exposures among what could be a consortium of many diverse countries. Even if constructed as a domestic effort, the exposure to international law suits is not clear at this time. Underwriters do not presently have a basis for assessing either the possible origins of claims or their severity.

However, an effort to develop SPS, combined with a close liaison with the world insurance market, would undoubtedly result in insurance for many SPS exposures. A consistent educational process will both allow underwriters to identify periods of exposure, for which policies could be designed, and would allow increased market capacity for these risks to achieve required levels.

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GLOSSARY

AAU	Associated Aviation Underwriters
COMSAT	Communications Satellite Corporation
COTV	Cargo Orbital Transfer Vehicle
DOE	Department of Energy
ESTCO	Earth/Space Transport Company
GEO	Geostationary Orbit
GW	Gigawatt, 1 GW = 1,000 megawatts
HLLV	Heavy Lift Launch Vehicle
INTELSAT	International Telecommunications Satellite Corporation
LEO	Low Earth Orbit
MARISAT	Maritime Satellite Corporation
NASA	National Aeronautics and Space Administration
Occurrence	Accident including continuous or repeated exposure to conditions which result in bodily injury or property damage, neither expected nor intended from the standpoint of the insured
Risk	Exposure to financial loss
POTV	Personnel Orbital Transfer Vehicle
Satellite Life	Economic viability
Severity	Intensity of loss
Tort	Illegal act not involving breach of contract
USAIG	United States Aviation Insurance Group
Volatility	Instability

I. INTRODUCTION

This report represents the beginning of a process to educate the insurance industry about the Satellite Power System. The report is divided into three sections. In the first section a general history describes how space risks are being insured today. This is followed by an attempt to identify the major risks inherent to the SPS. The final section presents a general projection of insurance market reactions to the Satellite Power System.

II. HISTORY AND DEVELOPMENT

A valuable means of assessing the future insurability of SPS is to examine the origins of satellite insurance and trace its development. Although SPS represents a much larger and more complex risk, it is important to bear in mind that insurance for commercial, telecommunications satellites was once regarded as improbable. The nature of space and its removal from the common stream of commerce make it an unlikely place to do business, but insurers are aware of a change in this attitude. Their willingness to assure the financial risk for orbiting satellites could be expanded to cover much larger space risks in the future.

The principal risks inherent to the SPS concept are connected to those activities carried out in space, or what shall be referred to in this paper as the "space segment." This is not to imply that the ground segment does not pose enormous liability and financial risks. The construction risks affiliated with the building of one, 100 km² rectenna site involves the accurate laying of approximately twice the concrete used on Hoover Dam. These risks, however, are readily observable and involve familiar materials used under fairly common construction techniques. The construction of large structures in space, on the other hand, presents both unusual materials constructed under truly alien conditions. For this reason the bulk of SPS risks involve space operations as opposed to ground activities.

A. History

Satellite insurance was first conceptualized in 1965 and has since grown rapidly in order to keep pace with the proliferation of telecommunications satellites worldwide. As will be shown, the growth of the spacecraft insurance market has primarily resulted from three key factors:

1. The education of the underwriting community in satellite economics and technology.
2. The steady compilation of reliability statistics and other actuarial data pertaining to both satellites, launch vehicles and earth stations.
3. The increase in insured satellite programs and the subsequent development of a premium base to support losses.

These steps will have to be retraced in the event SPS requires insurance protection. As the following historical analysis will show, a unique partnership must be formed between the insured, the broker and the insurance marketplace if future space risks are to be dispersed among the world underwriting community.

Limits on the forecasting of future phenomena through historical analysis are well known. A review of the history of spacecraft insurance and its rapid growth should not be construed as indicating that all these coverages could apply to SPS. Just as the engineer faces inherent problems with scaling up technology to those proportions required by SPS, so, too, does an insurance analyst run into similar problems when "scaling up" today's \$100 million in coverage to the billions in possible limits presented by the SPS project. A comprehensive overview of possible market reactions is outlined in Section IV of this report.

The first insurance written for a commercial space program was for the Early Bird launch vehicle prior to launch. The insured in this case was COMSAT, who has since insured the majority of their commercial space ventures.

Up until the formation of COMSAT, all satellite ventures had been government efforts--deriving the major part of their funding from NASA. Previous to Early Bird, NASA had launched the first communications satellite in geosynchronous orbit, SYNCOM, and had cooperated with RCA on the RELAY Satellite. The results of these and other early efforts resulted both in an enhanced knowledge of simultaneous receive/transmit transponder technology and a firm grasp of geosynchronous orbital acquisition.

All these early programs indicated the usefulness and economy of satellite telecommunications. It was obvious to many experts in the field at this point that interactive communications was on the verge of a major transformation. As the SPS studies are today spurred by increasing energy demand, so telecommunications of both media (TV, voice, telephone) and data for a growing international business community.

Given both the important role satellites played in business and government and the significant investment behind their deployment, discussions concerning their insurability became an important topic from

the outset. It was recognized during the policy design phase for Early Bird that satellites posed a number of phases of risk to the operator. The launch phase in particular was viewed as critical by both insurance analysts and satellite operators. They perceived correctly that the bulk of the financial risk inherent to any satellite-based system was grossly exposed from intentional ignition through station acquisition. Not only was the value of the satellite at stake, but also:

1. The cost of the launch vehicle
2. The cost of launch and relaunch services
3. The revenues to be generated by the satellite's operation.

Early meetings with underwriters on the subject of launch insurance were unsuccessful due primarily to their lack of familiarity with space-related risks. An educational process was subsequently initiated between the U.S. broker and the underwriting community aided when necessary by NASA and the leading aerospace manufacturers in the U.S. and Europe. Seminars were held in both London and New York designed to:

1. Demonstrate the reliability of satellites and launch vehicles by discussions of their components and various subsystems.
2. Define the insurance capacity required for current satellite programs and outline the probable growth in the industry.
3. Ask for dedicated capacity for satellite risks.

At this phase, the primary goal was to gain support for launch insurance, which was perceived as being the most critical phase in any given satellite program.

In 1968, Intelsat III, F-1 failed to achieve station acquisition and was lost. Including this launch attempt, six attempts had been made to place a commercial satellite in orbit. Of these, two failed to achieve synchronous orbit--one due to an apogee kick motor problem and the other (Intelsat III, F-1) due to a launch vehicle malfunction.

During discussions between COMSAT and a major insurance broker following the loss of F-1, COMSAT voiced an interest in wanting to insure the remaining Intelsat III launches. Using the information compiled from numerous meetings with COMSAT's financial and technical personnel, the broker quantified the risks involved and prepared a report that was presented to underwriters. At that time, the broker believed that the insurance market most likely to understand and accept the risk analysis was the aviation market. The three leading aviation groups in the world were approached. They were the Lloyd's of London, Associated Aviation Underwriters (AAU), and United States Aviation Insurance Group (USAIG).

After extensive negotiations, during which launch vehicle and hardware reliability were outlined, the London Market and AAU agreed to insure the launch failure risk for the remaining Intelsat III launches. The period of risk was defined in the policy as "the failure, within 45 days of its launch, of an Intelsat III spacecraft, after all reasonable efforts by COMSAT, to achieve a synchronous orbit having the circularization and inclination parameters as defined herein." The limit afforded under the policy was \$4,571,250 which represented COMSAT's financial interest in any given Intelsat III launch. Coverage was provided for one launch failure in a five launch series excess of a one launch failure deductible. The market was not prepared at that time to provide launch failure coverage on a first loss basis. F-2, 3, and 4 were subsequently launched successfully. F-5 then failed due to a launch vehicle malfunction and the series was extended to include an additional spacecraft. F-8 failed to achieve synchronous orbit, but this loss constituted the deductible under a separate launch policy designed for the final three launches. Underwriters, therefore, were not required to make a loss payment for the series.

Both during and after the Intelsat III program the concept of spacecraft insurance grew more and more appealing to both satellite operators and the underwriting community. As reliability data for launch vehicles, such as the Delta Class, grew in volume, a more accurate reliability assessment could be derived. Seminars were held to present detailed information on new technology used by satellite systems and showing the economic advantage provided by their use. It was at this later point, in 1971, that the concept of launch insurance was further refined.

An analysis of the Intelsat III system after orbital acquisition pointed out a flaw in launch failure policy design. It was evident that defects acquired during the launch phase prevented operation of the

satellite to design specifications after station acquisition, and yet a loss of this nature was excluded from the launch policy. This fact was made eminently clear to underwriters by the example of Intelsat III, F-7. Although the spacecraft had been launched successfully, a malfunction made it necessary for it to expend extra station-keeping fuel to remain at the proper orbital inclination. This resulted in a decreased life span for the satellite. To provide coverage for this type of anomaly it was necessary to redesign the definition of launch failure to provide coverage for insufficient fuel on board following station acquisition or for damage to the satellite resulting from improper operation of the launch vehicle systems. The launch insurance program for the Intelsat III program incorporated this new wording.

Following the design and successful placement of launch insurance for the Intelsat IV A, Marisat and Comstar programs, a new exposure namely, the orbital "life" of the satellite, was examined and successfully marketed for the RCA system. It became evident that the total failure or impaired life of a satellite once in orbit was just as great a risk to a satellite operator as a launch failure. Once again, the same process of education utilized for launch insurance was repeated. The initiation of this process with the SPS risks will greatly enhance the insurability of its various component parts. Satellite life insurance for telecommunication spacecraft has, in effect, laid the groundwork for financial protection of space ventures. The willingness of underwriters to insure revenues generated in space will serve as a precedent for their examining the SPS.

By demonstrating the reliability of satellites and defining the various key criteria that support their in-orbit functions, a policy was developed that indemnified the operator not only for total failure of the satellite, but also for partial loss of key life-support systems. Station keeping fuel levels, electrical power generation using batteries and solar panels, telemetry and tracking systems were all defined in the policy and their partial failure resulted in a payment equal to the operator's projected loss of revenues due to the satellite's depleted life span. Satellite life insurance was first placed for the RCA SATCOM satellites, with coverage being provided for three years after station acquisition.

Since then, the key to both launch and life policies has been their flexibility. As the number and use of satellites increased, the insurance coverages they required became equally diverse. The satellites became larger and more complex, thereby requiring more comprehensive definitions of subsystem requirements within the policy. Transponders increased radically, as did their channel capabilities--from Intelsat III's 1200 voice circuits and 120 watt output in 1968 to Anik's 5000 circuits and 300 watts of power in 1972. The Intelsat V spacecraft, to be launched in late 1980, will have 12,000 circuits powered by 1,241 watts of power collected by its 51 foot solar array.

The end result of this growth was the need, in every instance, for individually designed policies for satellites. Although satellite insurance started with only basic knowledge of satellite launch and orbital requirements, the insurance industry has today developed enough expertise to comprehend complex programs comprised of an entire generation of satellites and involving the interactive revenue streams of myriad channels.

B. Present Coverages

1. Satellite Ground Property Insurance

Satellite ground property insurance provides coverage for those first party exposures related to a spacecraft's prelaunch ground operations. The policy insures against loss or damage to:

- a. Each spacecraft to be used in the series
- b. Each launch vehicle, complete or incomplete, intended for use in launching spacecraft in the insured series
- c. Any related launch equipment while located at the launch site

Coverage can also be arranged for extra expense incurred as a result of loss or damage to the property owned, when such loss or damage results in deferral or termination of the scheduled launch. Additionally, it is possible to include coverage for business interruption which results from loss or damage insured under the ground property policy. This coverage applies only to revenues which are completely lost, as opposed to delayed, as a result of an insured loss.

Due to the differences in contractual agreements, the risks insured and periods of time for which coverage is provided will vary from one program to another. Depending on the insured's requirements, ground property insurance can be provided for any or all of these phases:

- a. While the insured's property is in transit from the manufacturing location
- b. While the insured's property is stored at and undergoing testing at the launch site
- c. During the pre-ignition phase, which begins with the commencement of operations to mate the spacecraft to the launch vehicle, and ends upon launch attempt, which is defined as intentional ignition of the first stage engines.

Coverage for related launch equipment is provided while the equipment is located at the launch site and terminates when the equipment leaves the launch site or when the insured no longer has an insurable interest in the property, whichever occurs first.

Coverage relating to the spacecraft and launch vehicle normally terminate upon launch attempt. In order that no gaps in coverage occur, the ground property termination wording is identical to the launch failure inception wording.

2. Launch Failure

The purpose of the launch failure policy is to indemnify the insured for the cost of both a replacement satellite and launch in the event of a launch failure as defined in the policy. The focal point of the policy is the definition of launch failure, which is tailored to each insured's unique requirements. The definition contains specific technical criteria relating to the spacecraft's orbital position, fuel and power supplies, physical damage, and spacecraft control systems.

Launch failure insurance can be written on a "first loss" or "deductible" basis. In a first loss placement, underwriters are simply required to pay a loss when the first launch failure, as defined in the policy, occurs. When coverage is arranged on a deductible basis, the insured elects to absorb the first loss, and underwriters will pay each insured loss which occurs after the deductible has been exhausted. Since this obviously decreases underwriters' chances of payment, the rate charged for a deductible placement has traditionally been significantly lower than that charged on a first loss basis. Whichever alternative is selected, the premiums paid are subject to a return of between 25 percent and 33-1/3 percent in the event no loss is paid under the policy.

As mentioned earlier, penalty insurance enables the insured to fix the cost of the launch failure coverage. The amount to be insured is the difference between minimum premium attainable through return of the no claims bonus, and maximum or standard premium. In the event the no loss return is not payable under the terms of the launch policy, underwriters will remit the amount insured under the penalty placement. Launch failure insurance terminates when the satellite achieves station acquisition and all criteria for a successful launch have been met. Again, to ensure that no gaps in coverage occur, this termination wording is identical to the inception wording of the next coverage--satellite life insurance.

3. Satellite Life Insurance

The purpose of satellite life insurance is to provide coverage for failure of the spacecraft to commence operations or its failure to operate as the insured intended once in orbit.

The definition of failure is the key element of the satellite life policy, and is, once again, tailored to meet the insured's specific requirements. The elements of loss include failure of the satellite to maintain the required orbit and position, unbudgeted use or loss of station keeping fuel, inability to generate and store power necessary to attain the design life of the satellite, and finally, failure of the communications subsystem to function as intended. With respect to transponder failure coverage, underwriters usually require that the insured accept the risk of loss for a certain number of transponders, and this is accomplished in the form of a deductible.

Satellite life insurance can be arranged to respond on a total or partial loss basis, subject to a maximum indemnity in either case. Additionally, as described with respect to launch failure insurance, life coverage can be arranged on a first loss or deductible basis. Although the no loss premium return was at one time a feature of satellite life insurance, underwriters no longer offer this aspect as a component of life policies.

The amount insured under this coverage may be determined by calculating the replacement cost of the launch vehicle, launch services and spacecraft. In cases where the satellite system is being established for profit-making motives the insured limit may also be determined by projecting the loss of revenue resulting from loss of the satellite.

4. Liability

Spacecraft liability insurance provides coverage for the insured's legal liability to third parties arising out of the operations prior to launch at the launch site, during launch itself, and during the spacecraft's orbit. These exposures may be considered by underwriters to be of an aviation nature, and as such are sometimes excluded from the insured's general liability program.

Spacecraft liability coverage is written on a broad form basis, and is carefully worded to include the additional insured, hold harmless, and waiver of subrogation requirements normally found in spacecraft purchase and launch services agreements.

Liability to third parties was minimal during the era of expendable launch vehicles. All personnel affiliated with pre-launch activities either indemnified or held harmless the satellite operator in the event of bodily injury. Sometimes operators were also contractually relieved of physical damage suits through agreements with the prime satellite contractor. After intentional ignition, the range-safety officer could abort the launch if possible damage to neighboring areas appeared imminent.

With the advent of the shuttle (STS) and the heavy-lift launch vehicle (HLLV), the liability exposure will change somewhat. Multiple payloads, the possibility of bodily injury to crew members and the increased frequency of orbital flights will create more opportunities for damages and resultant claims. Doubtless the exposures presented by possible environmental damage and the financial suits of hundreds of contracting parties will require a specialized approach to risk management and insurance. In contrast to this, the STS has the advantage of onboard pilots versus the expendable vehicle which gives the STS more flexibility. Additionally, the potential liability of STS users will decrease in light of NASA's new authority to indemnify users.

C. Conclusion

Each of the satellite insurance coverages--ground property, launch failure, life, penalty and liability--are written for a three-year term. Due to present reinsurance requirements, this is the maximum attainable policy period. It is currently possible, where a longer policy period is desired, in cancelling and rewriting at the policy's anniversary to obtain the required term of coverage.

Insurance capacity for all these coverages has increased dramatically over the last seven years and it is expected to continue growing. As will be discussed in Section III of this report, the enormous dollar limits perceived in the SPS program will require a more coordinated approach in expanding present capacity to SPS requirements. Coverages, as well, will have to be radically changed to reflect the requirements of SPS space operations.

The historical trend, however, has been positive. Space risks are being underwritten and the insurance community has reacted well to the challenge of space commerce. Whether this trend can or will expand to SPS proportions remains to be seen.

III. IDENTIFICATION OF RISKS

This section broadly outlines those areas of risk inherent to the SPS project as currently conceptualized. Risk, as used in this study, refers to those areas of the SPS concept that present an exposure to financial loss to the managing company or its contractors or subcontractors. It also refers to indirect exposures incurred by rule of law, such as liability to third parties.

The primary detriments to a complete, quantitative analysis of the system are obvious. The system is still a conceptual entity with few proven reliabilities available for a large scale insurance assessment. At this phase, such components as the design of the SPS satellite remain unknown and capital costs and ownership still remain theoretical. To quantify the magnitude of program phase and component risk and its insurability requires proven reliability and monetary analysis--both from the engineering and financial viewpoints.

Of particular importance in determining risks are the contractual agreements between all concerned parties. As will be discussed in the forthcoming liability section, the contractual allocation of third party risks is a crucial element in determining the exposure to third party law suits. Additionally, contracts between parties designate which participant assumes financial risk of loss or damage to a particular phase. Inevitably, all these phases interrelate, and this in turn makes designation of financial responsibility to a single party difficult. Delay or damage incurred by one contractor may create repercussions throughout the entire construction schedule. In this way "risk" becomes as much an outgrowth of contractual obligations, as the result of any one given physical exposure.

It is possible, however, to identify insurable risks inherent to the SPS concept in the same way as it is possible to broadly outline risks for any number of large, future projects. Marine insurance brokers were responsible for a large amount of off-shore drilling rig risk management designs before the first rig was even built. Many such projects require such studies before financing can be secured. Often risk management programs are utilized in determining equitable sharing of exposures during final negotiation of contracts.

The key to a definitive insurance assessment for SPS inevitably rests on what is accomplished between the present study phase for SPS and the actual decision to erect an operational satellite. During this period tested reliability for all aspects of the program will have to be demonstrated. Actuarial data will have to be compiled for underwriters review and the sharing of contractual risks will have to be outlined. Insurable exposures will thereby become more clearly defined and their interrelation with other phases will be indicated. Only through this process will underwriters be willing to devote their capacities towards legal and financial protection for the SPS effort.

As a prelude to the survey of SPS risks, a summary of the means of determining "risks" is appropriate, especially when performed on so theoretical a model.

Each phase of the SPS effort was first assigned to one of the two broad areas: ground segment or space segment. It was decided at the outset that an insurance program for SPS would require a sharp delineation between exposures occurring on the ground and those arising out of activities in space.

For each one of these segments, only direct-loss exposures were examined. Exposures to third parties and related legal liability exposures are covered in a separate section due to their unique character and far-reaching ramifications for the entire SPS system.

Each segment was then examined by a review of the reports published on the DOE/NASA SPS reference system. For the ground segment, a review was made of the following ground phases:

- Research and Development
- Rectenna construction and maintenance
- Pre-launch activities

For the space segment the following phases were reviewed:

- Pre-launch
- Launch and landing

- Space construction and maintenance
- Satellite performance

Each program phase of the ground and space segments was assessed both with a hard financial viewpoint, utilizing the estimated indemnities as set forth in Satellite Power System Financial/Management Scenarios, and a soft financial viewpoint, based on review of all major material available. The soft review is a subjective analysis of those risks perceived as being highly flexible in the risk of loss they present. The hard analysis focuses on risks that were perceived as being unavoidable and reasonably measurable even at this conceptual stage in the SPS design.

For example, in approaching the Research and Development stage we realized we were not in a position, at the present time, to assess the volatility of R&D activities. The development of a microwave phase control system, if delayed, could cause slowdowns in other areas, yet the extent of this exposure cannot now be appropriately quantified. What is known, however, is the cost of R&D ground activities over a 17-year period. Assessment of this overall phase resulted in a harder analysis. In comparison, the extent to which a delay in phase control development could effect other segments of the program can only be surmised at this point, resulting in a soft assessment.

There were also disparities in the analysis between our assumption of crucial exposures and those assumptions made by the SPS Concept Development and Evaluation Program itself. The most obvious disparity was a zero launch failure rate assumed by the SPS guidelines. It is our opinion that the launch phase of the SPS program represents a crucial focal point for the success of the entire program. The loss or delay of key payloads or personnel could have far-reaching ramifications for the six-month satellite construction period set forth in Systems Definition reports. Even considering an average of one launch per day, a single launch failure could result in the identification of system deficiencies throughout the HLLV fleet. The resultant delay could jeopardize a tenuous cash flow situation. It could also result in increased life support systems for crews and equipment already in orbital positions ready to receive an unhampered flow of materials. With regard to this risk, therefore, we have included the launch failure exposure within all sections of this preliminary insurance assessment.

Another exposure requiring further study hinges on the life span/decommissioning of the satellite itself. Given the large quantities of unique materials (i.e., gallium aluminum arsenide (GaAlAs)) used in the satellite, it is hard to envision a negligible salvage value after 30 years of use. Although the return-on-investment analysis shows payback with profit after this period, an insurable risk could occur if decommissioned SPS satellites were cannibalized for key elements, such as rare metals used in slipring brush assembly of the satellite rotary joint. The question therefore arises as to how a satellite is decommissioned and whether salvage would, in fact, be available for a second generation of satellite collectors.

Related to this problem is also the question of power transmission degradation. If the life (i.e., economic viability) of the satellite is to be protected through insurance, the rate of energy output, due to solar blanket or klystron degradation, must be outlined. If maintenance of the satellite includes replacement of worn components, in order to supply 5 GW at the rectenna site, then decommissioning with no salvage after 30 years requires closer scrutiny. In light of its unknown implications to the system economics as a whole, therefore, we have elected not to discuss satellite decommissioning in this report. It is assumed that the 30-year life span is only utilized in order to show the econometrics of satellite pay-back and not to indicate slow degradation and abandonment of the satellite.

With all phases of the total SPS risk, the principle question left unanswered is "who is being insured?" As was discussed earlier, review of contractual interrelations are necessary in order to determine exposures. Basic to this dilemma is the unanswered question--what will be the primary agency behind coordination of the overall SPS project and what will its contractual relationships be with SPS contractors and subcontractors as regards liability and financial loss?

The question of ownership is critical when identifying risks. Exposures can be minimized or enhanced depending on their government, private or quasi government/private affiliations. For example, a government launching agency launching a government payload assumes the same risk of loss due to launch failure as a private consortium undertaking the same project. However, a government launch loss may not have the catastrophic impact on a broadly based budget for which additional funds may be available. In contrast, a private sector loss may result in damaged cash flow to financial institutions, such as banks, and severe budgetary drains affecting material availability and project completion. NASA, therefore, could assume an increased exposure to financial loss compared to a private company attempting to develop the same types of systems.

The question of ownership becomes an even greater issue when discussing third party legal liabilities. XYZ Corporation operating a launch facility can have itself held harmless from bodily injury or property damage incurred by its contractors or subcontractors, but it will always be open to suits brought by third parties. Additionally, a government agency can be sued very similarly to a private entity, as a result of the Federal Tort Claims Act. A quasi-government/private organization, however, may be granted special immunity to third party liability claims through the legislation in which this body was created. It should be recognized that the U.S. Government is absolutely liable under the Convention on International Liability for Damage Caused By Space Objects (TIAS 7762) for damage to third parties, be it a public or private space object. Claims for compensation would be payable through diplomatic channels under this Convention for damage covered by the treaty. In all three situations above the risks are the same, but the actual exposure varies according to ownership.

The question of ownership will be discussed extensively in Section IV, but it is an important concept to bear in mind when considering both the identification of a given risk and the magnitude of loss it represents to the managing entity.

A. Research and Development

As stated in the introduction to this section, the risks presented in this phase are relatively unknown. It is envisioned that the R&D phase for SPS would be carried out by a number of private and public organizations in many locations, some of which may be located outside the United States. In and among these organizations we assume there will be some kind of coordinating body that both monitors the results of research and aids in integrating research results into a master plan for SPS.

If this coordinating organization is a loose network with no direct financial stake in the SPS program, then there would exist no exposure to direct financial loss due to failures or catastrophic delay within the SPS research network. Each research organization, therefore, whether it be ESA, COMSAT Laboratories or Rockwell, would be responsible for its own financial losses. The overseeing organization would have no vested interest in the results of these companies and would, in no legal sense, be obligated to share in the losses of each participating company.

In this example, support for the organization could stem from dues levied against each research organization. Each company would be responsible for all of its own property and casualty coverages and would insure as it saw fit within the commercial insurance market.

In contrast to this informal R&D management organization is a formalized structure consisting of perhaps one international governing body or several regionalized entities linked by a central, governing organization such as the United Nations. This structure could be established at an early point in the R&D phase or it could develop gradually as positive findings supported the viability of the system and the need for a coordinating body became clear.

It is not the purpose of this paper to outline the organizational dynamics of SPS management, but it is important to realize that central responsibility for the SPS effort would result in a complex, financial risk for the parent institution. Along with organizational responsibility for coordination would come a fiduciary responsibility to adhere to financial guidelines and, where necessary, obtain insurance for interruption or depletion of the flow of money due to an occurrence or accident. The term "occurrence" has been emphasized in order to make a point concerning any and all risks and their appropriate coverages. Insurance does not respond to business risks that may create financial loss. There must be a single point in time at which a loss becomes apparent. The explosion and resultant fire at a klystron development plant is insurable. The risk of erecting that plant and suffering financial loss due to failure to solve a particular component problem is not insurable.

The degree to which the managing organization would be responsible for the losses of its members is impossible to project at this time. Preliminary estimates of R&D costs, excluding deployment and testing of an initial satellite, exceed \$76 billion dollars. Control of these funds may or may not be the responsibility of a single entity, but if so considerable investigation must be made into allocation of risk of loss to this \$76 billion investment cost.

Another area of risk affiliated with the R&D phase is the development of related industries to support the full-scale SPS effort should it materialize. The mobilizing of resource companies to meet the material demands of both the ground and space segments may or may not be contractually linked to the managing organization. The contractual link the managing organization has with related industries could present a sizeable loss in the event of bankruptcy or failure of the managing entity to utilize pre-specified materials.

In conclusion, there will be varying amounts of risk affiliated with the R&D phase. In the event centralized responsibility for R&D efforts is established in a single agency, even the most informal agencies may prefer hold-harmless agreements for first party losses from its contractors and subcontractors. This may especially hold true in the event the R&D effort is financed by a consortium of national governments.

B. Rectenna Construction and Maintenance

The primary assumption made regarding this particular phase of the SPS concept is that rectenna development and design is perfected during the earlier R&D phase. The risks identified in this section, therefore, only pertain to the construction and maintenance of rectenna sites serving as a receiving station for a fully operational system.

This phase of risk, excluding liabilities, represents the least severe phase of the entire SPS system. The rectenna system has received, in many ways, the greatest amount of preliminary design attention and certainly the greatest breakdown as far as real cost. As envisioned at present, the rectenna would contain approximately 2.5 million antenna panel elements all feeding to single diodes. Each panel in the array has a steel mesh ground plane with 75-80 percent optical transparency. The arrays are themselves supported by steel columns in concrete footings. The capital costs for the facility are shown in Exhibit 1 as follows:

CAPITAL COSTS FOR RECTENNA SYSTEM (in billions 1977 \$)

<u>Component</u>	<u>Investment Required</u>	<u>Percent of Total SPS Program</u>
Ground station	3.319	29%
Assembly and Support	.382	3
Transportation	1.386	12
Management and Systems	.517	4
Engineering and Integration		
Contingency	1.105	9
Total	6,709	57%

Source: Satellite Power System (SPS) Financial/Management
Scenarios

EXHIBIT 1

It must be noted that research into rectenna design has indicated there is much room for greater economy of design efficiency. The eventual building of 60 rectenna sites will certainly result in faster, more effective construction techniques, thereby reducing the duration of the building phase and affiliated risks of construction delay and related exposures such as workers' compensation.

As with all phases of the SPS program, the question of ownership is paramount in determining overall financial exposure. The SPS study seems to strongly postulate a management scenario where a government or consortium of governments would be financially responsible for the SPS space segment whereas the ground segment, namely the rectenna component, would be owned and operated by a utility, or private organization selling bulk power to utilities.

If this were the case, then worldwide insurance capacity, for SPS property and casualty risks, would be devoted primarily towards protection of the ground phase. Management aside, the major risks perceived with the rectenna construction and maintenance phase are:

1. Damage or delay to materials while being transported to or stored at rectenna site.
2. Construction delay costs to revenue parameters.
3. Extra expense costs due to rectenna modification or unforeseen technical changes.

4. Cost of repair or replacement of components beyond projected normal degradation rates.
5. Cost of energy from neighboring grid in the event major catastrophe causes severe or total cut off of electrical power.

Risks during the construction and maintenance phase, given private management and ownership, have to be divided into two broad areas.

1. Construction risks
2. Maintenance and operational risks.

It is conceivable that a number of private companies would be responsible for rectenna construction and would thereby be under contract to the managing entity. Construction companies would each be responsible for their own internal risks, such as workers' compensation, employers liability and general liability. However, their contractual link with the managing entity would probably involve a sharing of costs for construction delay. Given the high valuations of all the rectenna phases, a sharing of the risk of increased costs would be inevitable. This could be done through the use of insurance to transfer the risk or joint pooling of funds out of which would come extra expense monies in the event of lengthy delay or damage.

Exhibit 2 identifies the primary issues used in evaluating SPS from an insurance standpoint. The figure summarizes the contractual agreements and primary financial exposures of the ground segment, and the space segment as it affects the ground segment. The contractual agreements listed represent the potential for indemnification and hold-harmless clauses. Such indemnification and hold-harmless clauses are written into a contract between two parties in which the first party agrees to accept the legal liability exposures of the second party. Figures summarizing the contractual agreements and financial exposures of particular SPS elements and program phases accompanies discussion of these elements in the text.

KEY ISSUES ON RECTENNA INSURANCE EVALUATION

<u>Contractual Agreements</u>	<u>Primary Financial Exposures</u>
Between managing utility and construction companies	Cost of rectenna land site
Between rectenna utility and satellite operator/owner	Cost per rectenna by hardware component
Between managing utility and neighboring energy grids	Cost of construction delay at each construction phase
State/federal regulations pertaining to rectenna sites	Cost of energy from contingent grid
	Cost of maintenance
	Cost of consumer interface (transmission lines, etc.)

EXHIBIT 2

The property damage risk for the completed rectenna itself is minimized by both its extraordinary size and simplicity of design. The Alaskan pipeline was, in its size, comparable to the SPS rectenna concept, but risk was more severe due to the fact that interruption at one point of the system caused a shutdown of the entire system. Damage to any given point of the rectenna is easily accessible and does not necessarily result in cut-off of the entire operations energy output.

Construction delays are always an inherent risk, but it can be assumed that only a catastrophic delay in construction, such as a flood, extreme tornado damage or sabotage, would result in substantial damage to cash flow. Business interruption coverage, therefore, could be kept at minimal cost by having it apply only when actual cash flow is severely hampered. Once constructed, the rectenna will require periodic maintenance, the costs of which are assumed to be part of the capital investment scheme. Once a revenue stream is initiated, each rectenna will be able to pay for its own maintenance, and show a return on investment to its owners or stockholders. The start-up period, therefore, presents the greatest risk for financial loss.

C. Pre-Launch Activities

The pre-launch activities phase of the ground segment includes all those activities pertaining to the SPS project other than those operations directly related to rectenna operation and maintenance. The following activities are currently envisioned.

1. Reception of materials and packaging
2. Integration of fuel materials for launch
3. Command and coordination of terrestrial activities and interface with space segment
4. Launch and recovery operations

As with various other phases of the overall SPS effort, this entire pre-launch operation could be under federal control. Assuming that the overall space segment will be a government undertaking, it is unlikely that a private entity will be responsible for the majority of pre-launch activities. The present NASA launch services policy provides a blanket hold-harmless clause for materials supplied to NASA for government use. Suppliers are subsequently responsible only for physical loss or damage to materials before delivery to the launch facility. Delay or nondelivery of contracted components or materials periodically result in a damage payment by the supplier when a liquidated damages clause is included in such contract to reimburse NASA for the estimated cost of such a delay in delivery. Additionally, there may be positive and negative incentive plans attached to major components. Incentive plans allow for scheduled payments of additional monies in the event a particular component performs to contract specifications. Failure to perform results in a negative assessment against the contractor.

Government ownership and management of the launch facility, therefore, presents few insurable risks. There is, however, a possibility that the following areas of the pre-launch phase could be privately managed under government contract.

1. Earth Transportation System

This would involve the pick up and delivery of all required resources including:

- Building materials
- Command and control components
- Propellants
- Space transportation vehicles and components
- Personnel

Each one of these resources would be on an arrival/deployment schedule managed by the command and control center at the launch facility. The primary risk during this phase, therefore, hinges not only on the successful operation of each component, but also on its adherence to the overall program schedule.

Contractors and subcontractors to the launch facility management organization would probably be responsible for the risk of damage or delay between the manufacturing site and the launch and receiving facility. Payloads for launch would hopefully be scheduled in such a way that delay of any given cargo component would result in reintegration of supplies on hand into any of the six hypothetical cargo mixes. This would result in flexibility in the event any phase of material transportation is delayed.

Of prime concern is the transportation of propellants and components for HLLV operations. The proposed total fleet of four boosters and five orbiters with 175 flights per year demands a rapid turn-around of both boosters and orbiters. Delay during launch-related operations (i.e., HLLV turn-around/payload integration) could result in considerable financial loss of the transporting company. The primary issues on earth transportation elements are reviewed in Exhibit 3.

KEY ISSUES FOR EARTH TRANSPORTATION

<u>Contractual Agreements</u>	<u>Primary Financial Exposures</u>
Between transporter and component manufacturers	Cost of transporting vehicle
Between transporter and launch agency	Cost of cargo
Between transporter and payload integrators	Cost of occasional liquidated damages clause

EXHIBIT 3

2. Subassembly of Satellite Elements

As is the case with many of today's telecommunications satellites, subassembly and checkout of components is often conducted by private contractors at the launch site. This could also involve actual payload packaging in preparation for launch. Excluding the liability exposures, launch requirements will demand innovative approaches to the overall maintenance and checkout of materials. Once again, incentive exposures in the event of delay or damage to private facilities are at risk. The key issues are shown in Exhibit 4.

KEY ISSUES FOR SUBASSEMBLY OF SATELLITE ELEMENTS

<u>Contractual Agreements</u>	<u>Primary Financial Exposures</u>
Between fabrication subassembly contractor (F/SC) and launching agency	Cost of plant facilities
Between F/SC and component supplier	Cost of delay or damage to payload materials

EXHIBIT 4

As an organizational structure has not been developed for the SPS program, there is a possibility that the launch site will be managed and operated by a private entity. This could be done perhaps through an act of Congress similar to the COMSAT act. An SPS launch support company could be chartered with aerospace and utility companies each sharing responsibility for the operation. If this type of management were developed, the overall financial risk would have to be allocated equitably among all participants. The company would assume financial loss due to failure to deliver materials to Low Earth Orbit (LEO). The result of this organization would be one private company coordinating and allocating financial risks for both the ground segment and at least part of the space segment. The arrangement of such an organization is shown in Exhibit 5. Its primary financial exposures appear in Exhibit 6.

PRIVATE SPS LAUNCHING CORPORATION ORGANIZATIONAL CHART

EXHIBIT 5

PRIMARY FINANCIAL EXPOSURE OF PRIVATE SPS LAUNCH SUPPORT CORPORATION

- Cost of launch facility
- Cost of communications and operational network
- Cost of launch command and control facility
- Cost of payload/HLLV intergration facility
- Cost of HLLV recovery operations
- Cost of stored materials before payload intergration

EXHIBIT 6

D. Space Segment

The financial risks presently perceived for the space segment include the R&D program phase, transportation activities, and satellite construction and maintenance. The three space segment risk areas are discussed in this section. A liability analysis for the space segment is included in a special section at the end of this part of the evaluation.

The space segment of the SPS program represents the "riskiest" phase of the entire project. It can certainly be said that any phase of a program involving construction in space presents an enormous amount of risk due to human exposure to harmful radiation, effects of zero gravity, and a complete dependence on technology for life support. Also at risk are materials transported from earth at high cost. The hostile nature of space, therefore, combined with the engineering hazards of constructing large structures in zero gravity, does not represent the kind of risk underwriters are pleased to accept.

As stated in the introduction to this report, however, the world insurance market need only be shown a modicum of reliability for its support. The operation of nuclear plants and off-shore petroleum rigs were, at one time, regarded as uninsurable. Today the majority of them are underwritten, but only after extensive testing and demonstrated reliability was shown by the developers.

It is possible to envision and assess the risks of the rectenna sites well in advance of their actual construction, but the magnitude and complexity of the space segment represents a risk and overall indemnity of such magnitude that it is hard to imagine a valid analysis of all the risks until a demonstration satellite has already been constructed. For this reason it is assumed in this report that prototype space vehicles and related construction and life support system will have been developed in advance of operational use.

As has been discussed, it appears almost certain when looking at the entire SPS project that much of the R&D phase will have to be under government sponsorship. This is a particularly valid observation when considering the massive amounts of capital required by today's NASA programs. The total budget for development of the space shuttle (STS) is currently estimated at approximately \$7.6 billion dollars. Research and development costs through construction of prototype SPS satellite is currently estimated at approximately \$76 billion dollars.

The financial first party risks presently perceived are shown in Exhibit 7. The liability analysis for the space segment is included in a special section at the end of this part of the evaluation.

PRIMARY RISKS OF THE SPS SPACE SEGMENT

- a. R&D Phase
- b. Transportation
 - (1) Launch/landing
 - (2) Cargo/personnel transfer
 - (3) LEO/GEO extra-construction/support activities
- c. Construction/Maintenance

EXHIBIT 7

1. Space Risks During R&D Phase

As with the testing of rectenna related technologies, the R&D phase of the SPS development will inevitably include both test flights for orbital and suborbital space vehicles and the deployment and testing of space-based construction platforms. The risks for these R&D activities will be the same as those outlined in the upcoming operational phase assessment. The exposures, however, will be higher during the R&D phase for the following reasons:

- High valuation of prototype space vehicles due to their one-of-a-kind nature
- Unknown and/or untested flight performance tolerances
- Untested logistics in space station construction and deployment to high earth orbit

During the R&D phase of contemporary commercial aircraft, the risks are extremely high and this risk is often self-insured by the manufacturing company. Some manufacturers are able to secure insurance for this early stage, but the premiums charged for newly developed aircraft are high. Some insure the liability exposure and self-insure the risk of physical loss or damage themselves.

It is safe to assume, therefore, that any development and testing of space vehicles to be used in conjunction with the SPS space segment would have to be under the authority of the Federal government. This is not to say that the private sector will be excluded from this phase. Doubtless many private contractors, both foreign and domestic, will be utilized in developing the vast majority of space-related components, especially the space vehicles themselves. However, the risk of loss for testing will undoubtedly be the responsibility of the government(s) involved.

If private sector involvement expands to a managing role in the space segment as well, then the high risk R&D program phase will have to be reassessed. Certainly private firms such as ESTCO (Earth/Space Transport Company) which plans to own and operate its own shuttle fleet in the future, could participate in the operational SPS phase, but the high risk Research and Development phase demands Federal administration and responsibility.

2. Space Risks During Transport

a. Launch/Recovery Operations

This phase only includes the shuttle activity of the Heavy Lift Launch Vehicle (HLLV) and transferring cargo and personnel once in Low Earth Orbit (LEO).

As has been stated previously, the launching of materials into LEO represents the most critical phase of the SPS program. Problems in SPS construction in GEO or difficulty with other space vehicles such as the Cargo Orbital Transfer Vehicle (COTV) may delay scheduled satellite completion, but the entire program hinges on the continual flow of materials and manpower to LEO via the HLLV. This vehicle's reliability, subsequently, is of primary importance.

The HLLV is exposed to the following direct risks:

- Cost of launch vehicle
- Cost of cargo

The indirect exposures, however, pose even greater financial risks. They include:

- Cost of replacement vehicle
- Cost of delay to production schedule
- Cost of increased launches in order to minimize material delay

It would be hoped that the HLLV launch schedule would be designed in such a way as to allow substitution of other HLLV flights in order to make up for a mission's failures. Back-up launch vehicles will be especially desired during the first six months of the space segment in order to insure construction of the LEO base.

b. Cargo and Personnel Transfer

This phase often refers only to cargo and personnel transfers between space transport vehicles and or structures in LEO:

- Transfer of materials to COTV building site
- Transfer of materials to COTV for relay to GEO
- Transfer of crews to POTV
- Transfer of materials to LEO maintenance base

The movement of cargo will be handled both through direct mating, as with crew transfer to POTV, and through deployment and retrieval by smaller, interorbital vehicles. Frequency and total number of HLLV flights per SPS satellite will depend on selection of either the silicon or GaAlAs satellite options, as shown in Exhibit 8.

REQUIRED SPACE TRANSPORTATION FOR TWO SATELLITES

	<u>Silicon Option</u>	<u>GaAlAs Option</u>
HLLV Flights	375	225
PLV Flights	32	31
COTV	30	22

EXHIBIT 8

Considering a total HLLV cargo capacity of 424 metric tons, it is obvious that the transfer of cargos will have to be carefully orchestrated. Valuations for each of the six projected payload mixes will have to be determined. The key issues of LEO cargo transfer and handling is shown in Exhibit 9.

KEY INSURANCE ISSUES FOR
LEO CARGO TRANSFER AND HANDLING

<u>Contractual Agreements</u>	<u>Primary Financial Exposures</u>
Between LEO/cargo contractor and overall SPS management	Cost of cargo/transfer technology
Between LEO cargo contractor/subcontractor and HLLV Launching Agency and orbital transfer agency (COTV/POTV)	Cost of damaged payloads
	Cost of delay to mass flow

EXHIBIT 9

c. LEO to GEO Activities

This phase includes the transfer of cargo to the GEO construction site as well as those miscellaneous transportation activities between GEO and LEO bases and between interim space vehicles and cargo transporters such as the COTV and POTV. The basic exposure is of a business interruption nature. One study allows for a 20-day contingency in the event of LEO to GEO delays, which would allow for cargo losses or damage but does not allow for total loss of a COTV vehicle. Construction of each COTV requires 27 days and would also require additional materials from earth thereby requiring additional HLLV launches.

Coordination of materials flow, monitoring of all interorbital activities including propellant requirements and the shuttling of personnel would all be under the direction of the LEO to GEO phase management. The key issues are identified in Exhibit 10.

KEY INSURANCE ISSUES FOR LEO TO GEO ACTIVITIES

<u>Contractual Agreements</u>	<u>Primary Financial Exposures</u>
Between interorbital agency and LEO/ GEO facilities	Cost of interorbital vehicles (including cost of additional HLLV launches for materials)
Between interorbital agency and COTV/POTV agency	Cost of lost cargo
Between material supplier/interorbital agency	Cost of delay

EXHIBIT 10

3. Space Risks During Construction and Maintenance

Given a scheduled deployment period of 90 days, the satellite construction phase of the SPS program presents little or no tolerance for material, personnel delays or delays in construction. Each satellite option has its own requirements in terms of personnel and types of materials. However, the key element in all space operations, especially as regards SPS construction is time. The less time, the less financial exposure to systems failure and the higher price of additional LEO to GEO base support. Additionally, the indemnity placed on each material component at the GEO base is at its highest value. The cost of material per payload may have increased 50 fold between its arrival at the terrestrial launch site and subsequent arrival at the GEO construction site. The following elements, therefore, will become critical in determining insurable exposures:

1. Reliability of space fabrication techniques and their replacement cost at GEO
2. Degree of automation in the deployment of satellite components, their retrieval and interface with the overall satellite plan, and their flexibility in dealing with delays of materials or engineering redesign.
3. Training and reliability of construction crews in the handling and installation of structural, and solar power collection and conversion technology.

In order to design a master builder's risk policy for this type of exposure more must be known about the financial exposures for damage and delay to key components and the exposure to danger presented to the construction crews. Risk at this phase as shown in Exhibit 11, will be measured by GEO base ability to respond quickly to imminent danger to crew or materials. In addition, it will depend on its ability to work around scheduling changes in material arrival or prolonged delay. In the early phases, especially, there will be a need for continuous evaluation in order to monitor key production areas and monitor all costs.

KEY ISSUES FOR SPACE CONSTRUCTION AND MAINTENANCE PHASES

<u>Contractual Agreements</u>	<u>Primary Financial Exposures</u>
Between construction maintenance agency (C/MA) and material transfer agency	Cost of delay
Between C/MA and rectenna utility	Cost of lost materials or supplies

EXHIBIT 11

E. SPS Liability Exposures

Liability exposures inherent to the SPS concept are sizeable and will require contractual sharing of liabilities among all participants in order to spread the risk of potential liability loss.¹ Liability exposures for SPS can be categorized into three broad categories:

Contractual damages between SPS contracts and SPS managing entity

Tortious damages caused by SPS participants to nonparticipating third parties (i.e., general public)

International law suits brought against the managing entity stemming from alleged adverse ecological damages or violation of international treaty

Category 1 includes those damages caused by delay of scheduled material or service goals between SPS contractors as well as contractual penalties levied against SPS contractors by the SPS managing entity. Categories 2 and 3 include both direct damages caused by environmental or manufacturing occurrences, and international legal activity against the managing entity and its national affiliation.

In all categories there exists the potential for large suits, due to the high SPS valuations at each phase and tort claims exposures due to the potential for widespread effects of system operations on the general public.

In the Risk Identification discussion, (sections III.A through III.D) the only exposures examined were first party financial risks. That is to say, losses or damage to property owned by each managing agency. These property exposures, however, are only part of the risk that faces the SPS program at each step. Concurrent with property exposures, there are also the risks of physical loss or damage to property which the insured does not own and yet is legally liable. Additionally, there is the exposure to financial loss due to harm or injury to persons other than SPS contractor employees or employees of the managing entity. Finally, there is the exposure to suits from third parties. Third parties are those persons not directly associated with the SPS program who are injured through negligent acts and occurrences arising out of the insured's operations.

The basis of liability rests on the general assumption that "legal wrongs" inflicted by one party on another are punishable by rule of law. Legal wrongs can be further categorized into criminal and civil wrongs. In relation to SPS, criminal wrongs are, for obvious reasons, omitted, leaving us the realm of liabilities within the civil sphere. Civil wrongs can themselves be divided into:

Torts - or those wrongs independent of contract, and

Contracts - or wrongs involving a party's liability for breach of contract or stemming from implied warranties

Liability insurance is designed to cover precisely those types of civil wrongs outlined above, but only after considerable analysis of both the insured's operations and exposures to third parties. In the case of SPS, all aspects, both terrestrial and otherwise, involve exposure to both contractual and tortious liability, often from operations or systems that have never been examined by the insurance industry. Contractually, the liabilities are further compounded by the fact that all the operations and materials are in some way interrelated. Generally, it is assumed in today's legal climate that an occurrence caused by one part of a whole will inevitably involve lawsuits against all possible parties. For example, the crash of a commercial aircraft could initiate law suits not only against the commercial airline itself, but also against the maintenance contractor, the designer and manufacturer of the aircraft and possibly even the aircraft manufacturer's subcontractors. Many parties can be legally implicated in a given occurrence.

This is not to say that large claims will be awarded the plaintiff from all the co-defendants. Although in some cases this could certainly happen, the law tends to adhere to a doctrine of comparative negligence resulting in a majority payment by the co-defendant carrying the major portion of responsibility.

¹It should be noted that any discussions of liability exposures are from the viewpoint of the insured's legal liability to others for damages occurring from fortuitous events. The SPS program would not be implemented if there was any certain expectation of liability type damages.

The remaining defendants will be charged with payment of the claim proportional to the extent they contributed to the act.

In the case of SPS, it is easy to envision how such law suits could affect a number of involved participants. It is possible, as will be discussed in greater detail in Section IV of this report, to create a network of hold-harmless agreements between all terrestrial and space-related contractors subcontractors and the SPS managing entity; thereby preventing some law suits within SPS organizations. This network would not however, prevent law suits brought on behalf of third parties or as a result of willful misconduct or gross negligence. It also would not prevent interagency law suits being brought against SPS participants in cases of absolute or strict liability wherein an entity cannot, by law, relieve itself of responsibility, contractually or otherwise. The principle of strict liability is applied to few exposures today; nuclear energy and employee responsibility of workers' compensation are two examples. The use of a microwave transmission system and this system's possible harm to the environment and to telecommunications systems presents the possibility of absolute liability application through Federal ruling and international treaty.

Considering these diverse aspects it can be said that SPS will pose a number of liability risks for which both the managing entity and its affiliated contractors and subcontractors will undoubtedly be responsible. Once again, the aspect of ownership becomes all important. Quasi-federal/private development and ownership could preclude all claims brought by contractors against the organization and severely limit the amount recoverable by damaged third parties. Government development and ownership would probably self-insure all liability claims. Private ownership, however, especially if involving both domestic and international cooperation, will necessitate a broad allocation of liability exposures. All concerned parties could facilitate this sharing through both contractual agreement and by the creation of an SPS liability "pool" out of which could be drawn legal defense costs and claims monies for all but catastrophic losses. The catastrophic losses could be covered through a commercial insurance program designed to respond to either a single claim that surpasses a specified amount or to an aggregate situation, wherein insurance indemnifies the organization or consortium for all losses that in a specified time period exceed a fixed amount. Insurance policies, however, will only be issued by underwriters if the extent of possible damages can be estimated.

The management of liability risks will be discussed in detail in Section IV of this report. The liabilities are here outlined according to their contractual or tortious ramifications to the various program phases.

1. R&D Phase

Excluding the testing of space vehicles and related transportation hardware, the liability for damage to third parties will here be borne by each of the independent research organizations. In cases where technology is passed from organization to organization, bailment agreements will undoubtedly be used. Under such an agreement the bailor agrees to assume all liability arising from use of the specified unit(s) and agrees to hold the bailee harmless from such suits.

It is also likely that the SPS managing entity will not bear any contractual liability for material delays, but will be liable for systems integration into the master plan. It is foreseeable, therefore, that the SPS managing entity will be held contractually liable for integration or funding delays, but will be indemnified by its contractors and subcontractors against damages caused to third parties.

With some particularly hazardous phases of the R&D program liability can be limited by mutual hold-harmless agreements between all SPS participants. In this way each impleading participant is precluded, by contractual agreement, from other participants as co-defendants. The injured third parties, however, would still be able to file claims separately against each participant.

For research and testing of space vehicles and space-related hardware in space, it is doubtful that the private sector would be involved to the extent that liability insurance would be necessary. Currently, government launching and developing agencies today do not indemnify contractors against third party claims and these contractors accordingly purchase insurance. It is foreseeable, however, that a central domestic or international launching agency for SPS would indemnify suppliers for damages to third parties caused during that agency's operations. This indemnification could only pertain to the R&D phase of the program. The key elements of third party exposures is shown in Exhibit 12.

KEY INSURANCE ISSUES FOR THIRD PARTY EXPOSURES

<u>Contractual Exposures</u>	<u>Primary Financial Exposures--R&D Phase</u>
Liability to State and Federal government agencies	Transportation and use of toxic materials
Delay penalties and interparty agreements	Ecological damage caused by land disturbance
Liability of contractors and subcontractors to managing entity	Ecological damage caused by materials processing
	Damage caused by electromagnetic effects
	Damage caused by experimental launch or recovery operations

EXHIBIT 12

2. Launch and Recovery Operations

During the era of expendable launch vehicles, such as the Delta and Titan class boosters, there was very little liability exposure to either the launching agency or the payload owner. Because the missions were unmanned, missions could be aborted in flight if imminent danger was foreseen by the range safety officer. Additionally, the launch vehicles almost never carried more than one commercial payload, thereby precluding lawsuits between flight participants should one payload or the other be suspected of causing the damage. Both from the viewpoint of contractual and third party liabilities, therefore, all parties participating were kept relatively free from lawsuits. Accordingly, there has never been a third party lawsuit brought against a spacecraft owner or operator.

The SPS project, on the other hand, presents the following unique exposures to tortious claims.

Damage or injury caused to third parties on the ground due to launch/landing occurrence

Damage or injury caused to third parties in space or in spacecraft due to fault/negligence of piloting entity

Damage or destruction to property both on the ground or in space

Damage or injury caused by pollution, adverse environmental effects of launches or landings, microwave exposure

Assuming an average HLLV launch frequency of one flight per day, the chances for crash or emergency landing presents an increased exposure to claims by injured third parties. There is also an enhanced exposure to damage caused by one crew member to a third party contractor/employee riding aboard the vehicle. The latter exposure can be substantially decreased by contractual hold-harmless agreements between all passengers, but it is doubtful that these agreements would effectively prevent suits in cases of negligence or misconduct by the launch vehicle operator. This concept applies to today's airline common carriers and it would doubtless apply to the space carrier as well, although it should be noted that the STS is considered by NASA to be a contract carrier. The Warsaw Pact agreement assigns the doctrine of absolute liability to international common air carriers, but specifies a maximum monetary amount injured parties or their estates can claim. Government control of the launch phase could result in the passage of legislation limiting the launching agency's liability to a specified amount. Government contractors and subcontractors, however, could be left exposed to such suits, especially if they are involved in the HLLV design, construction or maintenance phases.

Aside from those liability exposures caused by direct damage, there is also the possibility of individuals claiming indirect damage, such as bodily injury or environmental damage caused by microwave energy. Possible sources for such claims are identified in the Preliminary Environmental Assessment report conducted by DOE. It is clear in this report that nonmicrowave effects may pose the most immediate challenge to SPS operations. However, the ramifications of possible terrestrial and atmospheric effects of microwave transmission must be more carefully examined. Even a cursory review of the current increase in environmental lawsuits unrelated to SPS points out the need for a complete analysis of all environmental ramifications of SPS. Exhibit 13 outlines a network of contractual agreements that could allocate liability responsibility between parties during the launch and recovery phase.

CONTRACTUAL NETWORK MATRIX FOR SPS LAUNCH AND RECOVERY PHASE

	Managing Entity	Spacecraft Manufacturer	LEO Station Owner/Operator	Launch Vehicle Owner/Operator	Launch Site Owner/Operator	Passengers/Users
Managing Entity		•	•	•	•	
Spacecraft Manufacturer	•				•	
LEO Station Owner/Operator	•	•		•	•	
Launch Vehicle Owner/Operator	•	•	•		•	
Launch Site Owner/Operator	•	•		•		
Passengers/Users	•	•	•	•	•	

EXHIBIT 13

3. Space Construction and Maintenance Program Phase

Liability exposures at this phase of the program can be classified into two broad areas:

Contractual and third party liabilities of satellite construction and maintenance entity

Contractual and third party liabilities of satellite owner/operator

It can be reasonably assumed during this period that there will be minimal exposure to suits arising out of damage to third parties. All personnel involved in SPS construction activities will either be government employees or private employees whose only recourse in the event of injury will be workers' compensation. Depending on the legal environment of space activities it remains to be seen whether employers liability will be a valid exposure in space.

The principal network of interrelating liabilities stem from damage or destruction of construction materials, or the satellite itself, and those contractual liabilities stemming from the resultant delay in both construction completion and energy transmission to the rectenna and power distribution to the utility grid. The allocation of these exposures could conceivably be limited to the SPS management organization, but it remains to be seen to what degree this entity would be responsible for revenue stream delay to the ground segment.

It is also possible that although construction and maintenance workers could be contractually prevented from filing suit against the SPS management organization, they could conceivably file suit against GEO equipment manufacturers and subcontractors. This would create a situation similar to an international airline disaster where the estate of a deceased is limited to a maximum claim from the airline, but is unlimited as to who else and how much it wishes to sue other participants, such as the aircraft manufacturer. In the event a situation such as this occurred with SPS, it is possible that the component manufacturer (defendant) could subrogate against related companies involved in SPS operations--perhaps the SPS managing organization itself.

The final major liability exposure a construction and maintenance entity would face would be suits originating from purported microwave damages. Although it can be envisioned that the rectenna management organization could face these suits as well, it is important to bear in mind that the microwave transmission emanates from the satellite. It can be assumed, therefore, that the satellite owner/operator will be exposed to suits from both specified space activities and related environmental damages to people or property on the ground.

IV. MARKET DYNAMICS

The purpose of this final section of the report is two-fold. First, an attempt is made to show how the risks affiliated with the construction of the SPS system present a unique challenge to the world insurance market. Second, some ideas as to how these risks could be managed throughout SPS development and operation will be discussed. The risk management assessment will describe many ways of minimizing risk, of which insurance will be only one. A basic strategy as to how to proceed with risk analysis from the present SPS Concept Development and Evaluation Program (CDEP) phase onward is also outlined.

A. The Insurance Market

This term refers to the worldwide community of underwriters that accept various forms of risk from companies, individuals and other organizations. On the face of these insuring companies they appear independent and solitary, but in fact all insurance companies are intertwined, albeit some more than others. Their affiliation is caused by reinsurance and joint capacity. Reinsurance is simply insurance for insurance companies. A risk for \$500 dollars assumed by a single insurance company is seldom kept in full by that company. An amount of \$100 could be kept in-house and the remaining \$400 of risk reinsured to, perhaps, four other companies. In this case, if a loss occurs and the original insurance company receives a claim, it will pay only \$100 with the remaining four reinsurers paying the balance--first to the original company and then to the insured.

This example of reinsurance is highly simplified but it demonstrates how insurance companies spread the risk of loss through reinsurance. Risks are almost never held in full by one insurance company. A products liability policy specifying limits of \$200 million, for example, may in fact rest with hundreds of insurance companies around the world after the reinsurance process is completed. The company issuing the policy may, with many types of insurance, keep only 1 percent of the total limits insured. In the event of a catastrophic loss, the issuing company handles all legal activity and initial payment of claims, but would eventually draw on the responsibilities of his reinsurers for their amounts.

This network is both good and bad. It is good in that it allows the widespread dissemination of risk. It also allows companies to assume risks larger than they could every hope to defend or pay. The adverse effect of reinsurance is that a catastrophic loss in one area of insurance can create repercussions throughout the market. For example, the severe hurricane damage to the eastern seaboard of the United States in the early 1960s caused such a strain on the reinsurance companies involved, that coverages unaffected by the catastrophe experienced a rate increase. The market, in effect, became so drained through this one series of losses that it was forced to seek a higher premium in-flow in order to recoup its losses. This had the effect of increased rates for many types of insurance.

The insurance market, therefore, can be compared to a pool of water. Extreme losses in one area can cause depletion throughout. Insurance companies stand alone in many respects, but they are intertwined inexorably with their reinsurance partners.

With any one particular coverage, however, there exists a nebulous limit on how much insurance can be placed on that risk. The word "nebulous" is used because this limit changes from year to year, month to month, even day to day. This limit on one type of insurance is called market capacity. For example, the current launch insurance market capacity for telecommunications satellites is approximately \$100 million. This is the maximum amount an insured can purchase for any given launch. There may be four or five launch programs underwritten within the next four years, but the most launch insurance each one can purchase is \$100 million. A comparative example is the market for products liability insurance. The capacity for this coverage can be more than \$500 million and hundreds of thousands of manufacturing companies can purchase whatever equal or lesser limits of insurance they require.

The insurance market is competitive, meaning that large risks can be assigned different rates by different underwriting organizations. This competitive aspect, however, applies more to common, widespread risks where there is wide exposure and a substantial premium base, such as homeowners or automobile insurance. The larger, more complex the risk the smaller and, thereby, less competitive the market. The market is even smaller when the risk involves very high limits and infrequency of exposure. Satellite launches pose large financial risks and relative infrequency. This means that underwriters run a constant risk of a sizeable claim for launch failure and yet have a long period of time to await the development of a premium base due to infrequent launches.

The ideal risk, therefore, is one that affords minimal exposure to a large claim while also being underwritten often, thereby providing a constant influx of premium. In this way, underwriters can

amass and invest a substantial amount of their premium inflow and thereby more than off-set the intermittent out-flow of substantial claims dollars.

Frequency and severity, therefore, are key elements in determining both a specific exposure's insurability and its market capacity. The closer these two elements come to creating a rough equilibrium, the more attractive the risk to the insurance market. High frequency/low severity exposures create high litigation costs and low indemnities, thereby reducing profitability. Low frequency/high severity exposures warrant higher premiums, but the low frequency means a decreased influx of premium. With the latter example, one severe claim could negate the premium income of several years. With the former example, low severity creates a low premium base with little profitability. An example of the low frequency/high severity scenario exists today in the satellite insurance field where 18 years of premium income to the spacecraft underwriting community (approximately \$44 million) has just been eliminated by the RCA SATCOM III loss which will cost this same community approximately \$77 million.

If SPS, therefore, is going to find support in the insurance industry, it must be analyzed from the viewpoints of severity and frequency.

B. Unique Aspects of SPS Activities

There are two primary aspects presented by the SPS concept that are unique:

Unknown volatility of familiar exposures--There are many aspects of the SPS project that are merely scaled-up versions of risks that have been underwritten numerous times. The construction of the rectenna site, for example, involves unknown materials integrated in a known way. What is unknown is the potential volatility of this phase when viewed as a component of the entire system. What are the risks behind its destruction or damage? What are the possible liabilities stemming from its reception of microwave energy? What will its legal liabilities be to component electrical grids?

Unknown volatility of unknown risks--This refers to those risks that have never been underwritten and which have an unknown volatility factor, such as space construction. What are the risks affiliated with the building of large structures in space and what are the effects of delay or breakdown? What are the financial risks involved with more than 300 launches for one satellite and who will be responsible for environmental damage?

To be insurable, risks must first be calculable. There must be a reasonable means of statistically estimating the chance of loss for a given exposure. This element is unknown for many of the financial/liability risks affiliated with the SPS at the present time. More quantitative analysis must be made of all aspects of risk before underwriters will be willing to participate as insurers.

Another unique element of SPS risks is that they are presently indefinite. Not only are the indemnities incalculable but the exposures themselves cannot be reasonably isolated from other phases. In order to be insurable it will be necessary to isolate all financial and liability exposures through the use of carefully constructed policy wordings. In this way, underwriters will be able to examine one particular peril and know that there is a negligible amount of linkage with other exposures.

In this same genre, the SPS insurance program must be designed to avoid excessive, catastrophic losses. If certain, isolated aspects of SPS operations present exposures to losses of an enormous nature, then that phase will be regarded as uninsurable and will have to be assumed by the managing entity.

With regard to all the above mentioned SPS idiosyncrasies is also the fundamental problem of market capacity and insurable limits. The nuclear industry has the only comparable problem in terms of both high plant valuation and possible liability claims. The SPS program, if realized, will require a concerted marketing effort in order to develop the required capacities. As is outlined in the forthcoming risk management section, this will involve not only the development of monetary reserves, but will also require coordination among the insurers in order to prevent a particular group of markets from being liable for an inordinate number of exposures. For example, the insurers and reinsurers of the launch phase will probably not want to also be liable for claims arising out of space construction activities. Coverages for SPS will have to be spread equitably among insurers in order to ensure that no one section of the market assumes too high a degree of volatile risk. A slight degree of loss among many insurers has a less adverse effect on reinsurance than a sizeable loss in one part of the market.

C. Risk Management

1. Ground Segment

Successful development during the R&D phase of ground segment risks could result in the insurance market being able to indemnify the rectenna owner/operator for the replacement cost of an entire facility. This would, in part, rely on a master property policy insuring each of the 60 rectenna sites through a central, coordinated property market. In this way, the premiums from all facilities would provide a premium base for physical loss or damage to any given site. Deductibles could be applied to each site of approximately \$500,000. This prevents underwriters responsibility for all but major damages to each site. It is also possible that underwriters will want to limit their exposure to total loss by assuming payment for catastrophic losses to a maximum of two rectenna sites. This coverage could be designed on either a per site or total indemnity basis.

Liability for the rectenna facility would be available at a maximum limit of \$500 million,¹ but would be limited to direct damages or bodily injury caused by occurrences other than

Damage in any way caused by microwave radiation

Damage in any way caused by the transmission of electromagnetic pilot signals from the rectenna to the transmitting satellite

2. Launch and Recovery Operations

Launch operations, if not under government ownership and supervision, could expect insurance for pre-launch activities as well as insurance for HLLV's. This coverage would exclude penalties against the insured due to loss or delay of SPS construction activities. Additionally, it is foreseeable that underwriters will only want to be liable for a specified number of launch failures, and then only failures in excess of a given number of deductible failures.

The principal structure of the launch program could take the form of a pool into which is paid dollar amounts in proportion to each participant's investment in the total SPS program. These participants could be the aerospace manufacturers, the satellite constructors and the utility consortium that will control the transmitted energy. This pool's funds could be managed by the central SPS authority and used to pay the costs of major repairs to launch vehicles or the launch site. Insurance would then be purchased to insure all damages that call for payments over a specified limit.

Liability insurance for the launch phase would probably be available to a total limit of \$1 billion, but only with a self-insured limit of \$5 million. This self-insured limit could be part of a larger liability pool out of which could be drawn claims dollars for intermittent occurrences. With further analysis of the launch phase it may be possible to insure for physical damage or property damage over a \$1 million self-insured limit.

3. Space Construction and Maintenance

Until the construction of large structures in space can be shown to be routine, it is hard to imagine insuring this phase of the SPS program. If this and previous phases are not performed under government supervision and financing it is possible that there will be little capacity left in the insurance market for this type of risk. It is possible, then, that builders' risk insurance will only be available on an excess basis. When all 60 satellites are erected, however, it may be possible to then develop an SPS satellite insurance pool into which are paid some of the revenues derived from the rectenna facility.

4. Special Liability Exposures

The two primary special exposures are:

Liabilities arising from the delay of the SPS construction schedule at critical points

Liabilities arising out of environmental damages caused by microwave transmission, launch/re-entry activities

¹This limit of liability, as well as the others mentioned within this paper, is derived from our best estimates in view of present day limits offered and anticipated future growth of insurance capacity.

A separate policy for each of these risks naming all SPS participants as insureds would have to be designed and allocated to an extremely wide number of markets. If a high degree of participation is secured, it could be possible to secure coverage for a total limit of \$500 million.

This liability coverage would exclude coverage for environmental damage caused by propellant effluents or related exposures. It would also exclude penalties or claims brought against the launching company for delays or nondelivery of materials to LEO or GEO. It could, however, include coverage for direct damage and injury occurring during the transfer of cargos or the mating of spacecraft while in orbit.

The key to insuring the first exposure, of course, is to structure construction and launch activities in such a way so as to minimize the effects of a delay on any phase of the 90-day construction schedule. If redundant materials and launch vehicles are readily available, insurance could be purchased to protect perhaps 50 percent of the delay loss up to a maximum of \$300 million. The remainder of the delay losses could be augmented through government participation and/or utility profits.

Environmental damages will require a unified plan, such as the Price-Anderson Act, to ensure equitable payments to damaged parties. An international agreement, perhaps one promoted through the United Nations, would guarantee intergovernmental indemnification of the SPS consortium over and above a prescribed limit of liability of, perhaps \$500 million. The act would ensure that claims for damages over this limit would be paid by the participating governments in direct proportion to the energy benefits they receive from the SPS system. Each government would in turn elect to either self-insure this risk or seek environmental damage insurance on the commercial insurance market. As the possible damages are not known at this time, it is impossible to judge if this type of coverage would be available in the future.

5. Cargos

The problem of claims arising from the nondelivery of materials in space could be alleviated by the development of a modified marine cargo program to insure either a given number, or monetary amount, of cargo losses both during the HLLV phase and extending to actual delivery of the cargos at the GEO construction base. This coverage could be arranged on either a scheduled or aggregate excess basis. A scheduled basis would result in first-loss insurance for each of the HLLV cargo mixes subject to either a per flight deductible or maximum indemnity per cargo shipment. An aggregate excess program would only pay for losses or damage to cargos in excess of a pre-stipulated amount of, say, approximately \$100 million. The program would then respond to all subsequent claims up to a maximum limit of \$1 billion.

As with the launch/recovery phase, the frequency of the risk creates myriad opportunities for many different kinds of policy designs. Self-insured limits, deductibles and insurance pooling could be structured in any number of ways.

6. Conclusion

The SPS effort will require the following strategy in order to secure equitable management of its affiliated risks.

Risk avoidance: Where at all possible, potential financial liability exposures should be avoided. This policy should be implemented in both technical design phases as well as financial management phases. Potential savings or technical innovations should be weighed against the possible increased hazards they present.

Self-insurance: Where possible, the managing SPS entity, its contractors and subcontractors, should assume the risk of financial loss for particularly hazardous or unknown phases of the program. Liabilities to third parties should be allocated among the participants, where contractually possible, and excess insurance sought where potentially catastrophic losses are possible.

Insure: A close liaison with the insurance market must be maintained if certain risks are to be insured. The SPS project office must develop a risk management/insurance division in order to facilitate the passing of large amounts of data to the world insurance market. Component and prime contractors for SPS research and development must arrange for general reliability and statistical information to be available to insurers.

Intermittent risk analysis: Detailed risk evaluations should be carried out on a regular basis in order to ensure proper coverage and maximum use of the insurance market.

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