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ALL-ELECTRIC SATELLITES – INSURANCE IMPLICATIONS

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All-electric satellites are expected to become a significant proportion of future geostationary communication satellites orders. The significant mass reduction of an all-electric satellite compared to a chemically-propelled satellite with the same payload, or the ability to include a larger payload for the same launch mass will start to reduce transponder prices and ensure satellite solutions remain competitive against terrestrial alternatives. The major disadvantage of all-electric satellites is the time it takes to reach geostationary orbit, which could be a number of months, even under nominal operations. Traditional space insurance policies include a provision such that a satellite can be declared a total loss if it does not reach geostationary orbit within a predefined number of days. For chemically-propelled satellites which require a handful of impulsive burns to complete the transfer to GEO such a loss is relatively easy to determine and for a situation, for example, where a satellite is delivered short of its intended apogee, the quantum of a loss, or whether it is worth proceeding with the orbit raising manoeuvres can be determined with confidence, relatively quickly. The situation for all-electric satellites will be different. For all-electric satellites it may be possible to overcome launch shortfalls or certain propulsion system failure scenarios by increasing the duration of the orbit raising phase. Satellite insurance policies cover the value of the space asset, which for a newly launched satellite would usually mean the replacement cost of the satellite, the replacement cost of the launch service and the cost of the insurance; the three main costs in any satellite project. Insurance does not usually cover the revenue that the satellite is expected to generate. Whilst the traditional satellite insurance policies have served satellite operators well there are failure scenarios for all-electric satellites which only reduce the level of redundancy, for example, but which could result in a significant increase in the duration of orbit raising. The increased duration of orbit raising will result in a financial impact for the satellite operator due to the loss of revenue associated with the delayed entry into service, but would not be covered by a traditional satellite insurance policy. This paper will consider, from an insurance perspective, the implications of moving to all-electric propulsion and suggest ways in which the satellite insurance coverage may need to be adapted to ensure satellite operators continue to be indemnified for the risks they face.

I. COMMERCIAL GEO COMSATS

Of 1,167[1] active satellites in-orbit (see Figure 1) only 212[2] are insured. By far the majority of the insured satellites (178[2]) are commercial geostationary communications satellites (GEO comsats). The GEO comsats sector forms the foundation of the US$195.2 billion[1] global satellite industry, providing a wide range of communications services. Whilst the commercial GEO comsat industry has seen considerable growth over the past two decades, competition from alternative services delivered via fibre or other terrestrial means, or from lower cost satellite options from China and Russia, has required Western satellite manufacturers and operators to constantly seek methods of lowering the cost per transponder.

Lowering the cost per transponder can be achieved by lowering the launch cost, either by using a lower cost service or by reducing the launch mass of the satellite, or by increasing the number of transponders that a satellite of any given size can accommodate.

Approximately half of the launch mass of a GEO comsat has traditionally comprised the chemical propellant(s) required for orbit-raising and station-keeping. For a typical GEO comsat this could represent approximately 2,000 – 3,000 kilogrammes of the launch mass. To reduce the propellant requirement and therefore the launch cost, electric propulsion was introduced on GEO comsats in the 1990's[3].

II. ELECTRIC PROPULSION

Whilst a number of electric propulsion technologies have been used on spacecraft for either operational or experimental purposes, the two systems which are currently used for GEO comsats are based on Electron Technologies Inc (ETI) Xenon Ion Propulsion System

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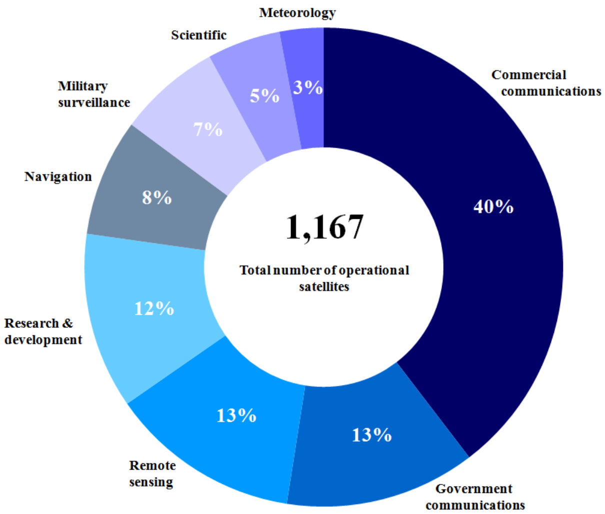

Fig. 1: Operational Satellites by Function (as of 2013)[1]

(XIPS)[4] and the Stationary Plasma Thrusters (SPT) systems using thrusters provided by Experimental Design Bureau Fakel or built under licence by Snecma[5]. Both XIPS and SPTs are examples of electrostatic thrusters. The XIPS units use a cathode to ionise a gaseous propellant (usually xenon) by electron bombardment. The positively-charged ions of propellant that result are then accelerated by an electric field and expelled from the thruster to provide thrust. The SPT thrusters use a strong electro-magnetic field to retain electrons produced by the cathode. Xenon propellant introduced to the thruster is again ionised by the electrons with the interaction of the electric and magnetic field expelling the ions at high velocity under the principle of the Hall Effect. Table 1 compares key characteristics of the ETI XIPS and Snecma SPT electric thrusters.

XIPS thrusters have been used on commercial GEO comsats since the launch of Panamsat's PAS 5 satellite in August 1997[7]. SPT thrusters saw their first use on a commercial GEO comsat with the launch of the Russian-built Yamal 101 and 102 satellites in September 1999[8]. Since the launch of AMC 12 in February 2005[9], SPT thrusters have also been used on Western satellites and are now commonly used on GEO comsats built by Airbus Defense and Space[10]; Space Systems Loral[11] and Thales Alenia Space[12].

Whilst electric propulsion has been used almost exclusively for station-keeping purposes to date, in March 2012 Boeing announced the first order for their "all-electric" satellite (the BSS 702SP[13]) which would for the first time see the full benefit of electric-propulsion and corresponding reduction in launch mass, by using XIPS thrusters for both station-keeping and orbit raising.

The Boeing order was a joint procurement from Asia Broadcast Satellite (ABS) and Satélites Mexicanos (Satmex) for four BSS 702SP satellites with options for a further four. At a rumoured price of approximately US$85m per satellite[14], and a launch cost of approximately US$30m per satellite[14] for a shared launch aboard a SpaceX Falcon 9, the 48[15] transponder all-electric solution promised to significantly lower the cost per transponder. Since Boeing's announcement all other GEO comsat manufacturers have announced their intentions to have all-electric versions of their platforms available.

The major disadvantage of the all-electric satellites is the extra time taken to reach GEO when using electric propulsion for orbit raising. The low level of thrust produced by electric propulsion thrusters will result in the orbit raising phase of a typical GEO mission being extended from perhaps a week with chemical propulsion to a number of months for electric propulsion. This will delay the start of revenue generation, albeit such factors can be built into fleet planning and replacement cycles by the satellite operator.

III. SATELLITE INSURANCE

The first insurance purchased for the launch of a satellite was in 1965[16]. At the time satellite insurance was handled by marine (cargo) and aviation underwriters. Since the growth in the commercial satellite sector in the mid-1980's, satellite insurance has become a class of insurance in its own right and the satellite insurance coverage design has matured. Satellite insurance is currently provided by over 40[2]

Thruster Type	ETI 25cm XIPS High Power Orbit Raising	Snecma SPT PPS 1350
Average Specific Impulse (seconds)	3550	1650
Thrust (mN)	166	88
Thruster input power (kW)	4.3	1.5
Total efficiency (%)	68.8	55
Thruster mass (kg)	15.9[4]	4.8[5]

Table 1: Key characteristics of ETI XIPS and Snecma SPT electric thrusters[6]

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insurers worldwide. Approximately US$750m of capacity[2] is available to cover any one satellite or any one launch.

Satellite insurance is usually purchased to cover the asset value of the satellite and not the revenue the satellite produces. For a claim to be paid therefore, an unforeseen and unexpected insured event must take place during the period of the insurance coverage which permanently impairs the performance of the satellite due to physical damage. Such insured events could include an electrical parts failure, a mechanical wear-out issue, a micro-meteorite or debris strike or damage sustained due to a space weather event. As there must be a permanent impairment of the satellite, an event that only consumed margin or that reduced redundancy would not result in a claim.

Satellite insurance coverage is usually provided for twelve months at a time. The first year of cover, termed "Launch Insurance" therefore covers not only the ascent to orbit, but also activities associated with the early operation phase such as deployments, orbit raising and in-orbit testing as well as the remainder of the first year in-orbit following acceptance by the satellite operator. Launch insurance typically terminates on the first anniversary of the launch date. In-orbit insurance then covers each twelve month period thereafter for the remainder of the satellite's life.

To cover the case where a satellite may be stranded in an intermediate orbit either due to a launch vehicle not achieving its intended orbit or because of a failure of the satellite's apogee engine, but where there is disagreement as to whether it will be possible to get the satellite on station, satellite insurance policies include a "long stop" provision. This provision usually states that the satellite can be declared a total loss under the insurance policy if it has not reached its final operating position within 180 days of launch.

IV. INSURANCE FOR ALL-ELECTRIC SATELLITES

As already described, all-electric satellites require a significantly longer orbit raising phase than chemically-propelled satellites. Whereas a chemically-propelled GEO satellite would normally complete orbit-raising within a week through the use of perhaps four or five near-impulsive burns of an apogee engine, the use of low thrust electric propulsion will extend the orbit raising phase to a number of months. This evolution of satellite technology will require changes to the launch insurance coverage if like-for-like cover is to be provided for satellite operators introducing all-electric satellites into their fleet, see Figure 2. Changes that may be required to the traditional launch insurance coverage are as follows:

- Policy Period: A typical launch insurance policy of a chemically-propelled satellite has a duration of twelve months and, as already stated, will cover launch, orbit raising, in-orbit testing and the remainder of the first year in-orbit. Within this period orbit raising usually takes one week, in-orbit testing up to two months and then the policy continues to cover operations for the remainder of the first year. During this time the satellite will see at least one full eclipse season in its operational configuration.

  Depending on the electric thruster technology used, an all-electric satellite will not complete all these same steps within a twelve month period. Orbit raising of an all-electric satellite could take in excess of six months[17] and whilst some in-orbit testing of platform systems may be possible during the orbit raising phase, payload testing will only be possible once the satellite arrives in GEO. If in-orbit testing still takes two months, it is likely that the satellite will only be ready for handover to the operator at the end of the twelve

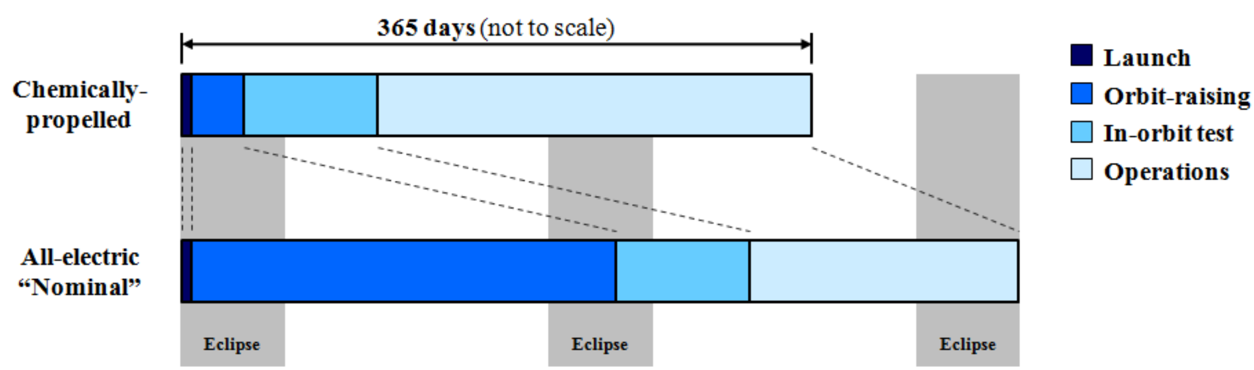

Fig 2: Typical mission phase durations for chemically-propelled and "nominal" all-electric GEO comsats

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month period. If an operator considers it essential to include an eclipse period in the satellite's operational configuration under the launch insurance policy the policy may need to be extended to last between fourteen and sixteen months to offer the same level of cover as a traditional launch insurance policy for a chemically-propelled satellite.

- Long stop: Whereas the launch insurance coverage for chemically-propelled satellites typically uses a long stop of 180 days, by which time the satellite can be declared a total loss in the event that it has not reached its final geostationary position, this provision will need to be amended for all-electric satellites. The 180 day limit is a convenient threshold and is not specifically related to the propulsion technology used or failure scenarios covered. It is however a sufficiently long time that it is safe to assume that the satellite will not be able to reach geostationary orbit if it has not been able to within this timeframe using impulsive propulsive systems.

For the all-electric satellites a single simple threshold for a long stop is not possible. The duration of orbit raising will be directly proportional to the power available. Anomalies affecting either the electric thrusters or the satellite's power system may have an impact on the duration of orbit raising. With that in mind, the long stop provision used in the launch insurance wording will need to consider the possible failure scenarios that may impact the duration of orbit raising and be sized so as to take into account the worst case scenario, such that a total loss is not claimable whilst there remains a possibility of the satellite achieving GEO.

V. NON-NOMINAL SCENARIOS

Other non-nominal scenarios also need to be considered for the design of the insurance coverage. As described above, any anomaly that affects the power available will potentially impact the duration of orbit raising for an all-electric satellite. A significant loss of power due to say a Solar Array Drive Assembly (SADA) failure, or failure to deploy a solar array will result in a significant insurance claim due to the permanent physical damage that the satellite will have suffered under such a scenario. However, assuming the satellite had been insured to cover its asset value, the insurance claim would be calculated based only on the loss of satellite capability, i.e. the lost transponder years suffered. The claim would typically not include any element related to the longer orbit raising phase, unless the long stop total loss provision was triggered.

There are however other scenarios which could result in a longer orbit raising phase but where no insurance claim could be made under a traditional insurance policy. For some all-electric satellite designs the low thrust available from an electric thruster means that to achieve an acceptable orbit duration both the primary and redundant sets of electric thrusters must be used to enhance the thrust during orbit raising. If a thruster or power supply failed early in the mission, the duration of the orbit raising phase would be significantly increased but under an asset-based policy the only impact would be the loss of a redundant unit so no insurance claim would be due. This is illustrated in Figure 3.

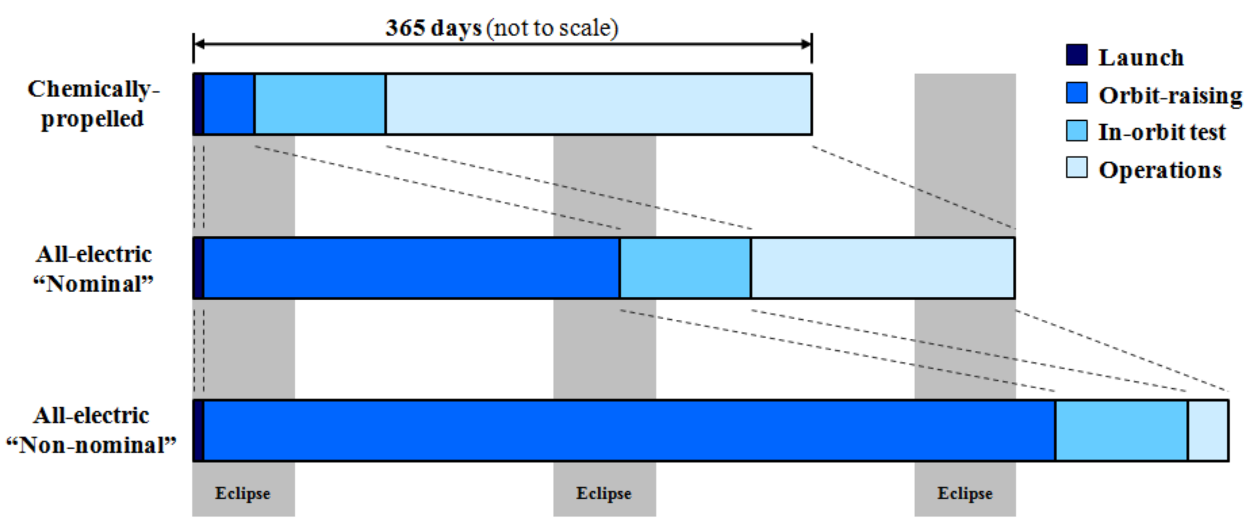

Fig 3: Typical mission phases including "non-nominal" all-electric GEO comsat

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VI. ALL-ELECTRIC INSURANCE

As a result of the greatly increased duration of orbit-raising for all-electric satellites, particularly in the event of non-nominal operations, there appears to be significantly greater financial consequences for a satellite operator using an all-electric satellite as opposed to a chemically-propelled satellite. Whereas an operator of a chemically-propelled satellite is likely to know within a few days to weeks if their satellite is working nominally, the operator of an all-electric satellite may see the orbit raising phase increased significantly and face a delay to the completion of in-orbit testing and start of revenue generation of a number of months. Under some scenarios the satellite operator may not be able to make a claim under a traditional satellite insurance policy.

It would appear therefore that along with the technological evolution that is represented by the all-electric satellites a corresponding innovation of the insurance policy will be required to cover the potential additional financial losses satellite operators face when procuring all-electric satellites. The proposed solution would be to incorporate a second section in the insurance policy protecting the loss of revenue that could arise from a delayed entry into service, as shown in Figure 4.

Insurance coverage for an all-electric satellite should, it is proposed, therefore consist of two sections as briefly outlined below:

- Asset Coverage: The first section would be similar to a traditional satellite insurance policy, covering the asset value of the satellite. As per existing policies, coverage would attach at Intentional Ignition or Launch and cover the satellite for permanent physical damage that may arise and which would impair the future operation of the satellite. Such perils would include the failure of the launch vehicle or the impacts of a SADA failure or failure to deploy a solar array as measured by reference to the number of lost transponder years. Such coverage would potentially differ from a traditional insurance policy, as discussed under Section III., in that the duration of the coverage may need to be longer to ensure in-orbit testing and potentially one full eclipse season is included, if such points are deemed relevant by the operator. The time period before the long stop provision applies will also need to be increased in line with the failure scenarios for each particular satellite.
- Loss of Revenue Coverage: The second section would be additional coverage that could be purchased by the operator of an all-electric satellite to cover the impact of a delayed entry into service. A claim under such coverage would be triggered by an anomaly (either on the launch vehicle or satellite) that resulted in the orbit raising phase of an all-electric satellite being extended beyond the nominal duration expected, and assuming that the anomaly was insufficient to cause a total loss of the satellite. Such an anomaly may result from the loss of a single thruster (for example) preventing the use of a high-thrust mode during the orbit raising phase.

Claims under such coverage would not be

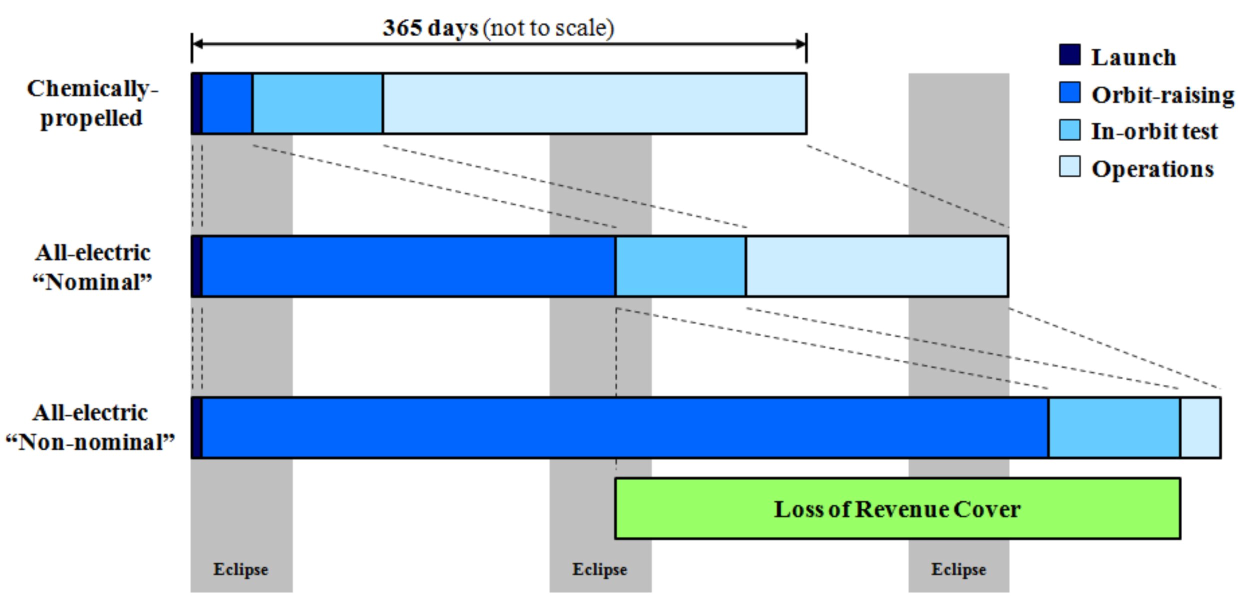

Fig 4: Proposed insurance coverage design for all-electric satellites

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related to the asset value but instead the loss of revenue due to the delayed entry into service. Metrics to quantify the loss would need to be established prior to launch but would need to recognise lease contracts agreed, contracts that could be negated due to the delay, expected transponder fill rates, etc.

VII. CONCLUSION

In conclusion, the technological evolution that all-electric GEO comsats represent will help to lower the cost per transponder of satellites and ensure that satellite-based solutions remain cost-competitive against alternative terrestrial solutions. The use of all-electric satellites do however result in a number of cases under which a satellite operator may face additional financial losses which may not be claimable events under traditional satellite insurance policies. As a consequence, the technological evolution of all-electric satellites requires innovation of the insurance product to ensure a satellite operator's position is protected.

This paper provides an overview of the introduction of all-electric satellites and a number of changes that may be required for the insurance of an all-electric GEO comsat. It is suggested that such changes be considered by all operators intending to procure all-electric satellites and corresponding insurance coverage.

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