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Risk management in the space industry

Insurance Institutes of Sussex & North Downs - conference

17 October 2019

Learning Objectives

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A brief introduction to how satellites and launchers work, how they are manufactured and operated and the business plan underlying the manufacturers, operators and downstream service providers, followed by a discussion of risk management within the space industry, its specific requirements and challenges and the recent and current market status.

After this presentation, you should be able to:

- Have a better understanding of the contribution of the space insurance industry to the worldwide space industry
- Understand the major insurance covers typically offered by the space insurance market
- Have a basic understanding of how the space market placement process and potential claims process works
- Be aware of the major actors in terms of clients, brokers and insurers

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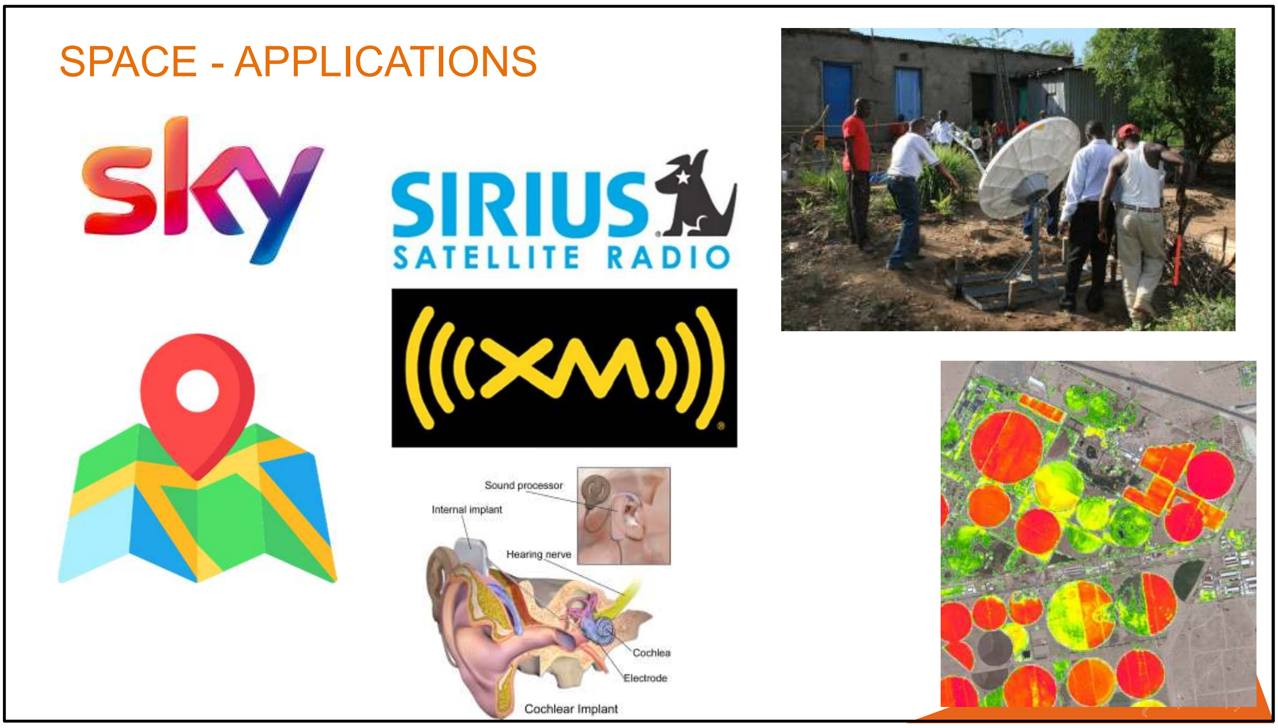
THE SPACE INDUSTRY

3



Space applications are much broader than most people realise.
We all know about

- Television broadcast – such as Sky
- GPS navigation systems
- Google earth

In addition, space applications include:

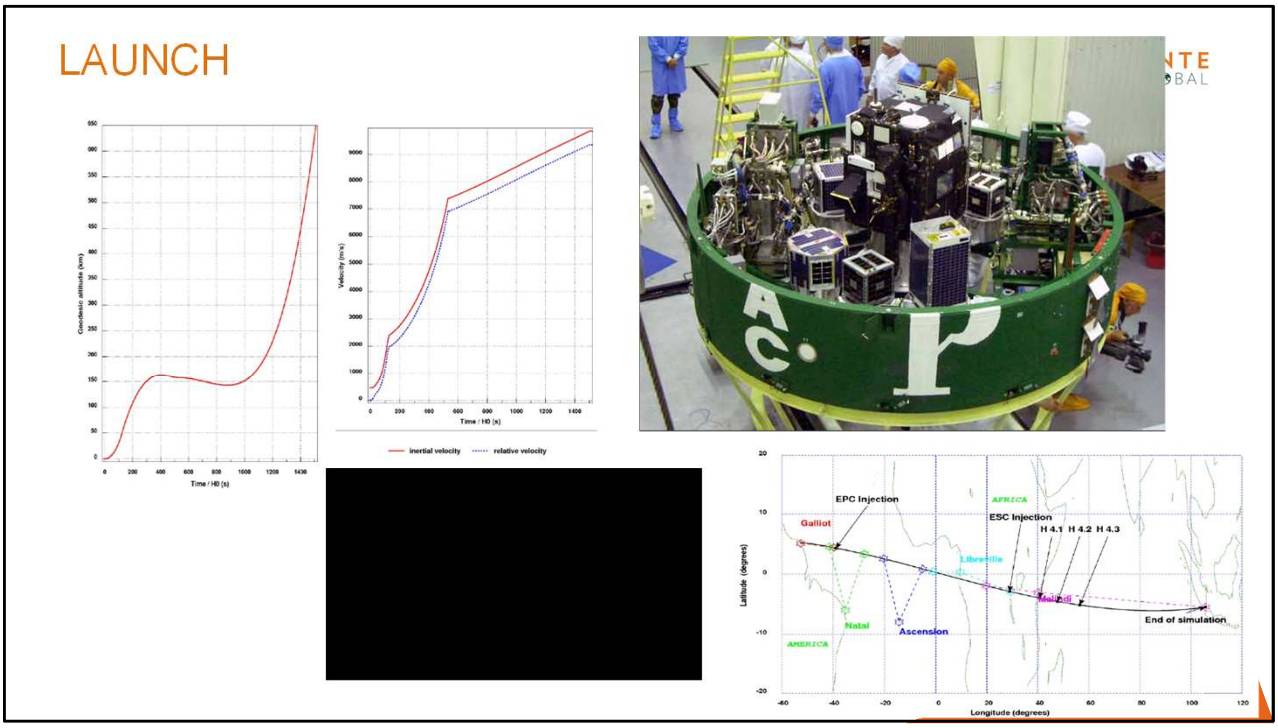
- Broadband to remote areas
- Radio broadcast
- Internet backhaul
- Banking transactions
- Civil engineering and agricultural, fisheries and coastguard
- Military surveillance
- Research into materials, biology etc.

And, in the future, potentially:

- Mining
- Manufacturing
- Power generation

MANUFACTURERS, OPERATORS, DOWNSTREAM PROVIDERS

Insured parties come in many shades:
Manufacturers have specific exposure during the manufacturing (Assembly, Integration an Testing, AIT), shipments and pre-launch phases, as well as by warranties during operations.
Satellite operators will have an asset exposure during lanch and in-orbit operation of their satellites.
Downstream service providers depend on the content or service delivered by space assets to provide products to their customers and will also have an exposure to the inability of those space assets to perform.
Launch operators (and satellite operators) have a third party liability exposure in case a failure causes damage, injury or death to a third party.
Governments are liable for launch activities which they have licensed.
Investors are exposed to the loss of their investment in companies which rely on space assets.



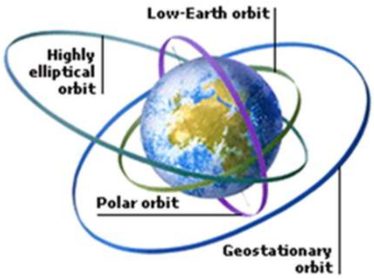
Orbit is about speed – not height - what goes up comes down, no matter how high it goes.

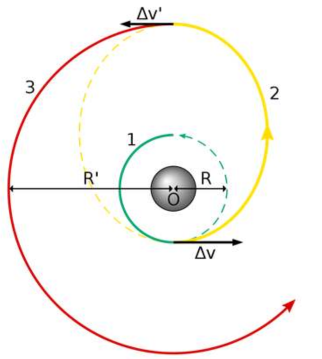
If there was no air resistance you could orbit the earth at a height of 1 meter, should you want to.

A launch will go up at first to get out of the atmosphere and reduce air resistance, but will then go along, gaining speed. Finally, it will go up again to deliver the satellite(s) on the target orbit.
Some launches carry several satellites – the record is around 80 in one launch.

ORBIT

$$\frac{mv^2}{R} = \frac{GMm}{R^2}$$

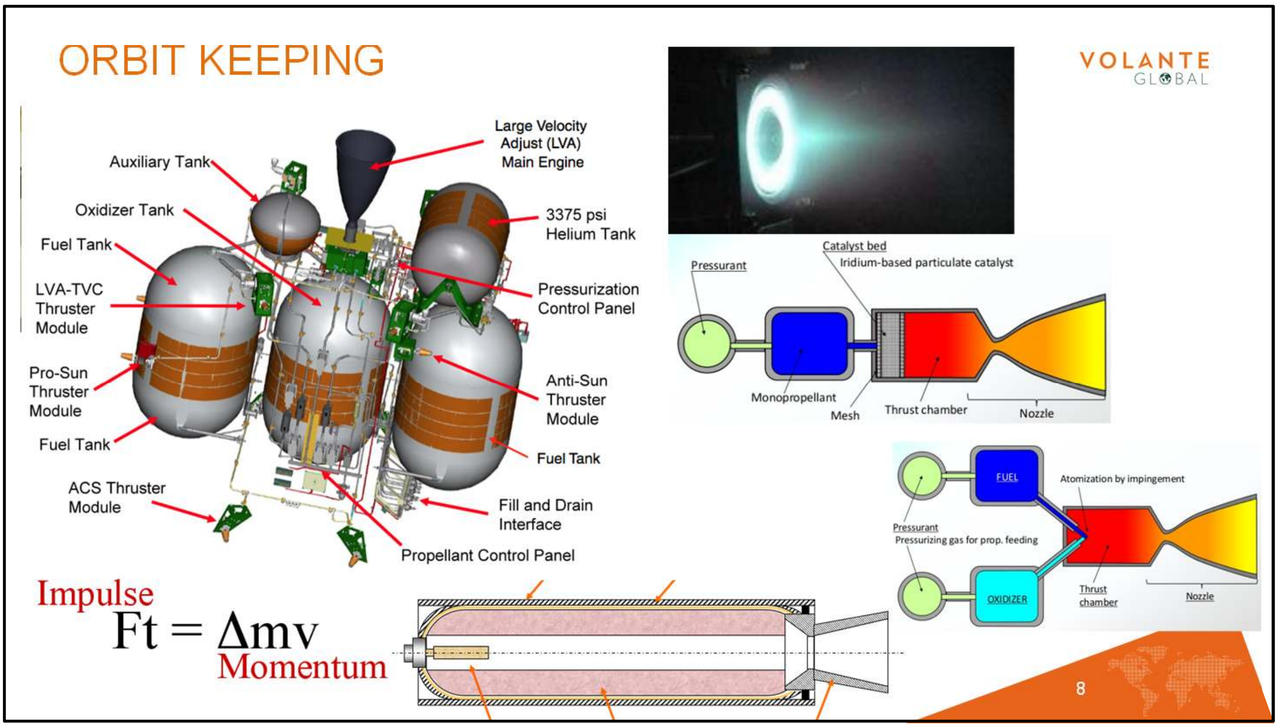




Altitude	Comment	v (m/s)	v (mph)	Period (hr)	Period (days)
-	On earth surface	7,918.88	17,717.81	1.40	
400.00	ISS	7,680.88	17,185.30	1.54	
600.00	Imaging satellites	7,569.65	16,936.45	1.60	
20,200.00	GPS	3,874.13	8,668.04	11.96	
42,164.00	Geostationary	3,074.57	6,879.09	23.94	1.00
384,400.00	Moon	1,009.96	2,259.69	675.27	28.14
149,600,000.00	Earth/Sun	29,787.78	66,647.60	8,765.76	365.24

7

When an object (a satellite) orbits another object (the earth), it is moving at a speed around that object which is so high that the gravitational pull between the 2 objects equals the centripetal force of the rotation.
Changing orbits is all about gaining or losing orbital speed. For circular ortbits, this is typically in pairs, raising first the apocentre of the orbit, then the pericentre, to achieve a new circular orbit.

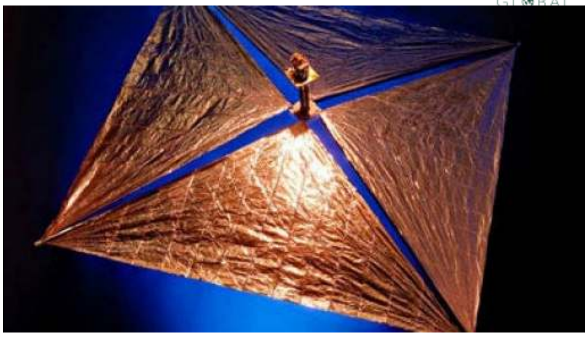


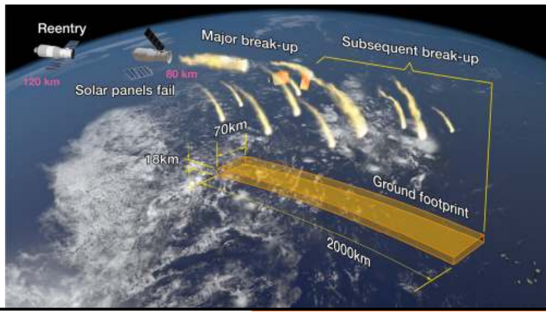
Once on orbit, satellites need to stay on orbit. Atmospheric drag, the influence of other planets and satellites and the other gravitational effects will perturb stable orbits. Interplanetary missions are also strictly speaking in an orbit between each manoeuvre and need to adjust their orbits to, for instance, enter an orbit around Mars.

This is the main role of Propulsion systems. Since there is nothing to 'push against' in space, these rely on the action=reaction or impulse principle.

The aim is to eject as little as possible mass at the highest possible speed.

DEORBIT, COLLISION AVOIDANCE

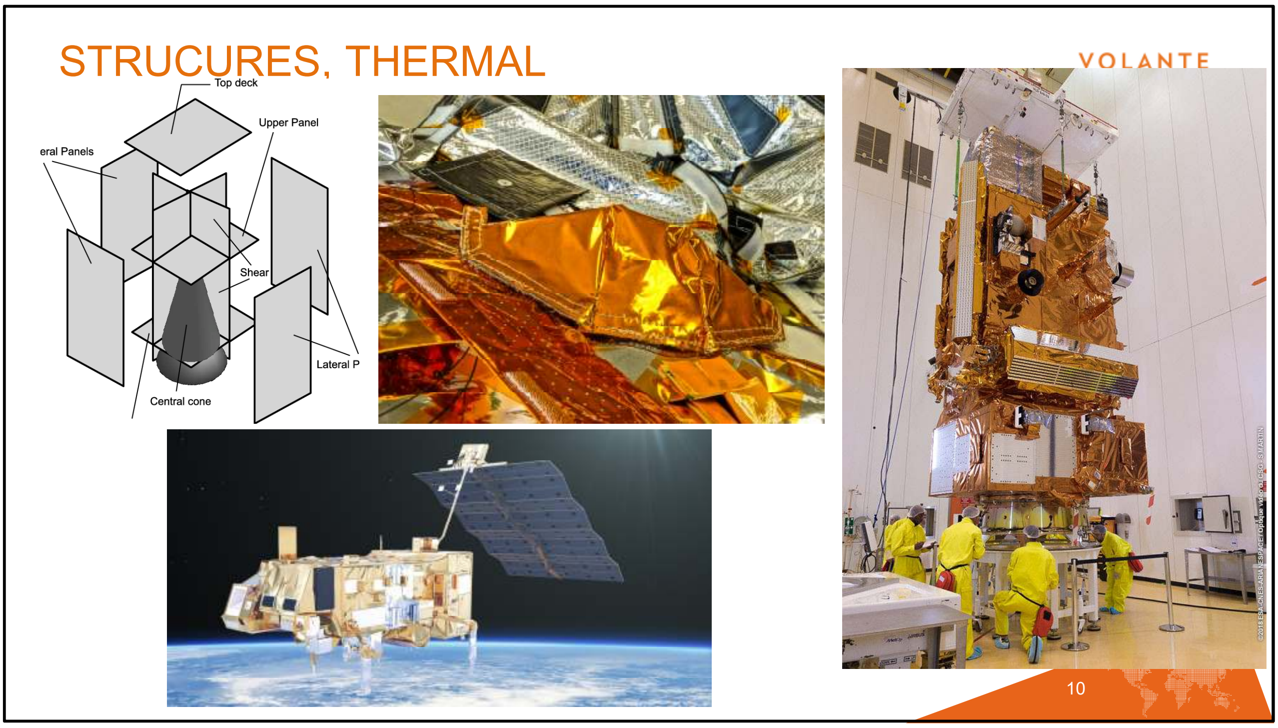




At the end of life, satellites need to be put out of the way. They cannot be returned to earth, but they can be deorbited into the atmosphere or put into an orbit far away. This means that the propulsion system must still work and that there is still propellant left... Or passive equipment such as solar sails, magnetobooms etc.

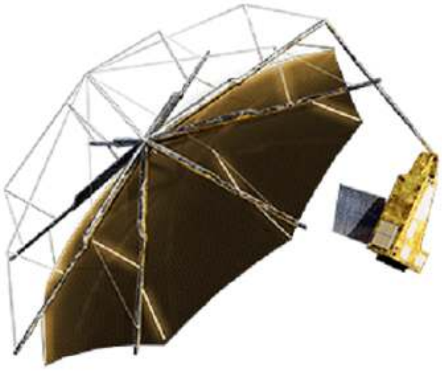
With more and more satellites in orbit, there is also a very real collision risk. Low earth orbiting satellites can make a dozen or so orbit adjustments per year to reduce the probability of conjunctions... Although these may not be required at all.

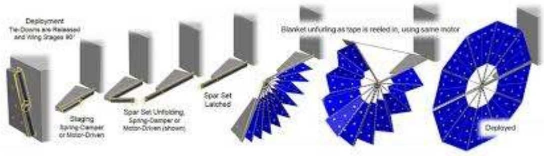
Upcoming projects should improve space situational awareness and allow better tracking/orbit control.

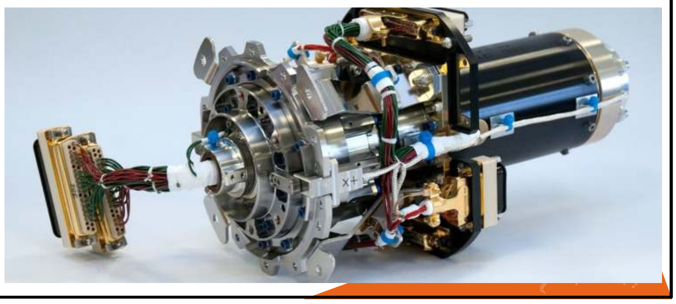


Once in orbit, structures are mostly useless... But satellites need to be able to survive the launch environment, and their structures are designed mainly for this.
On orbit, the thermal environment is very harsh. Very high (into the sun) and very low (in the shade) temperatures can change almost instantaneously. At the same time, the satellite has a lot of very warm equipment on board.
Higher temperatures mean higher failure rates.
Thermal stresses means that structures can break, wiring can crack, mechanisms can seize...

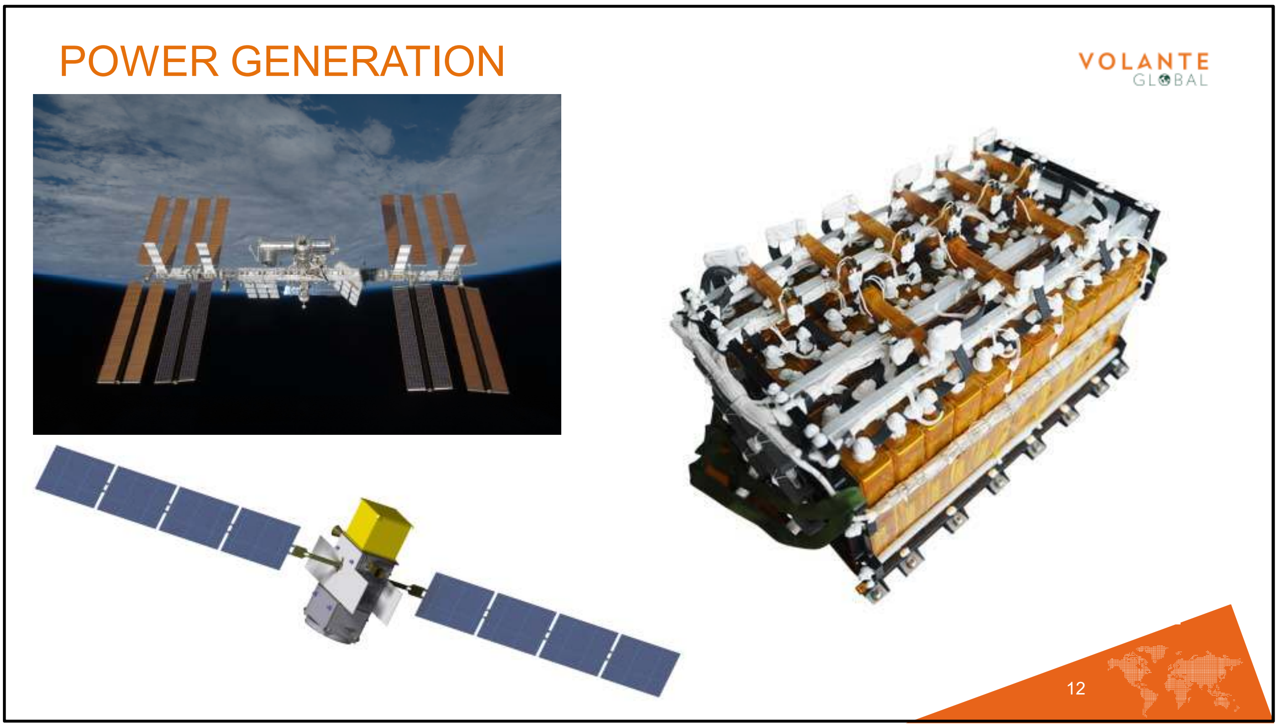
MECHANISMS







During launch, the satellite must fit within the launcher fairing, typically 4 or 5m diameter.
Once on station, it will want to have large solar panels, reflectors, booms, antennas etc.
It may also want to point instruments and rotate equipment.
Mechanisms must be strong enough to survive launch, yet light and small enough to be viable.
Often mechanisms are locked during launch with devices such as pyrolocks, thermal knives, memory metal...



Although it is possible to use nuclear power (deep space missions such as the Voyager probes where the sunlight becomes very faint) for all practical purposes, satellites use electrical power from solar arrays.

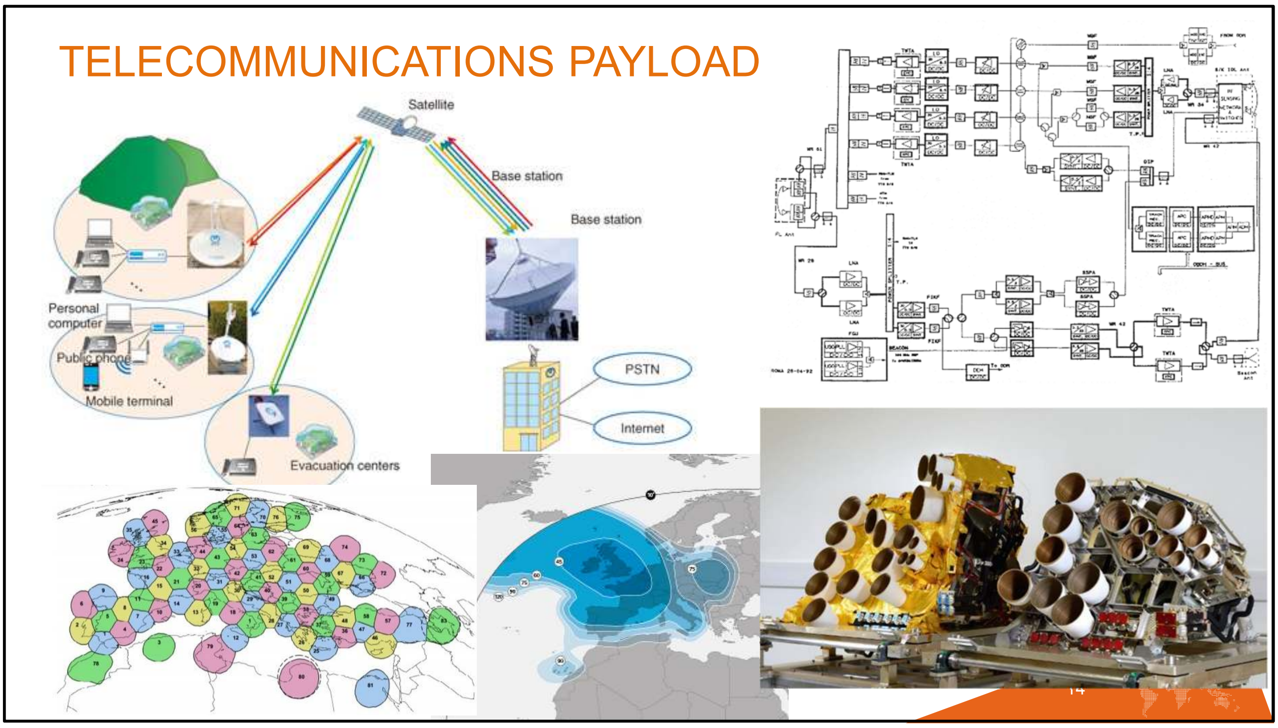
Big satellites today may need up to 30kW of power - the same as 20 kettles on full tilt, 24 hours, 365 days, 15 years without maintenance.

Almost all satellites will go through periods in eclipse, i.e. in the shadow of the earth, so in addition to solar arrays which may be up to 40 meters across, they rely on batteries for a couple of hours per orbit.

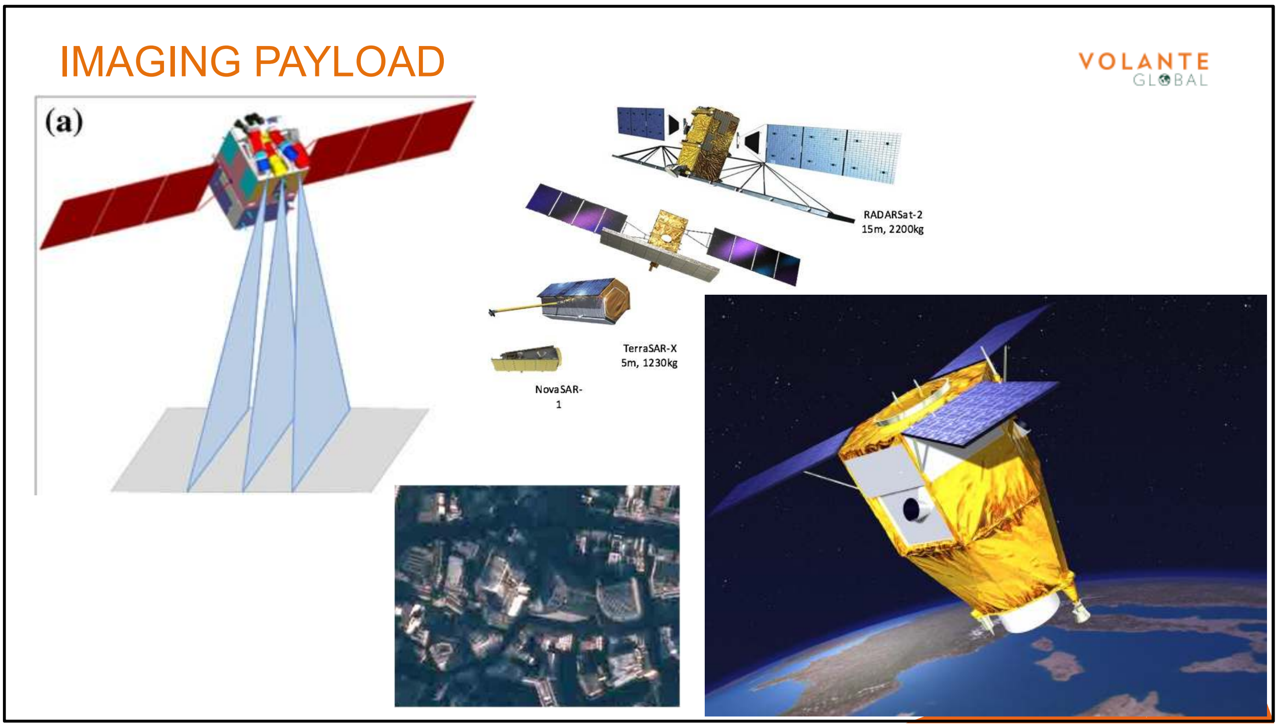
Power systems are critical; failures can give a lot of heat and plasma/corona effects can destroy satellites very quickly.

Attitude and Orbit Control System
To be useful, satellites need to be in the right place and point in the right direction. First off all, that means knowing where they are and where they are pointing, using sensors such as:
Sun sensor
Earth sensor
Star sensor
Gyroscopes
Magnetosensors
Accellerometers
GPS

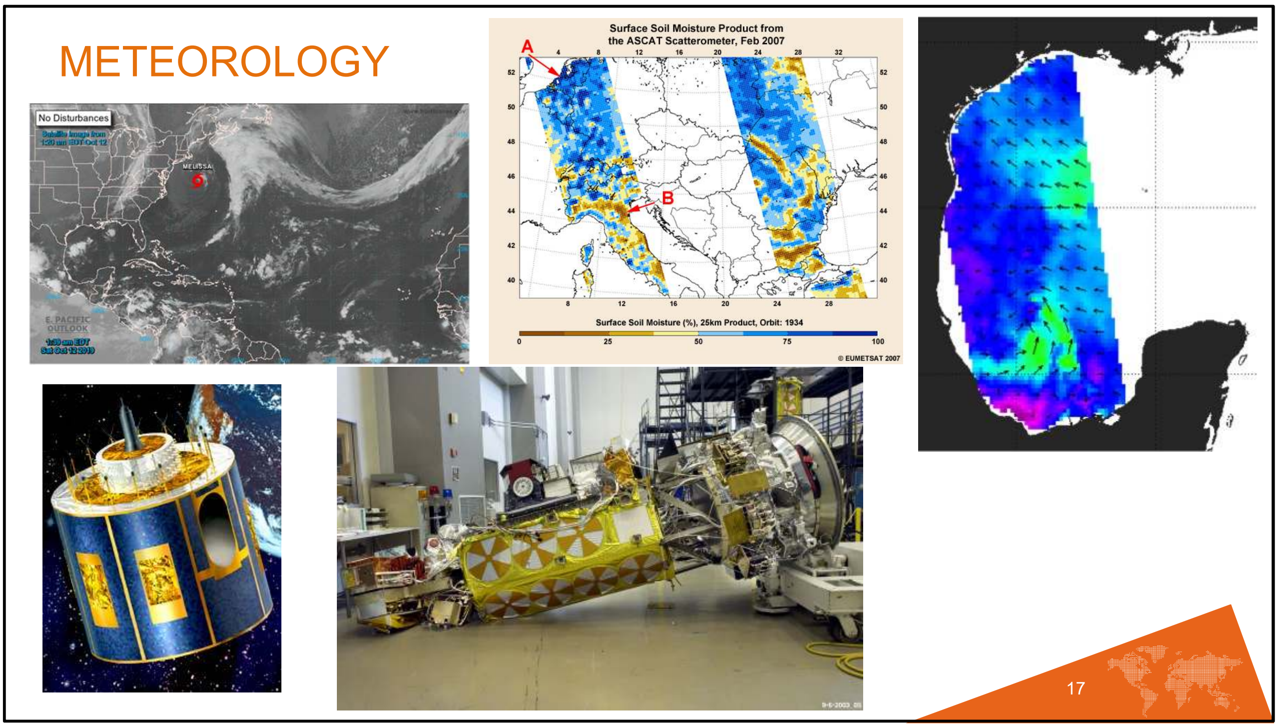
They can then adjust where they are pointing by actuators such as :
Propulsion system
Reaction wheels
Magnetotorquers
Control Moment Gyroscopes
Solar sails



The most common type of satellite is used for broadcasting of radio signals. In the old days, they were analogue signals used for TV or telephony, today they are digital signals for Internet, radio, TV, telephony.
Basically the satellite is a large amplifier - it receives signals from one or more upload stations, amplifies these and transmits them back again to receivers on Earth.
Modern payloads are able to split data from the same sender into streams for different receivers and recombine several streams into one bigger one. This allows applications such as broadband Internet and various 'over the top' services.



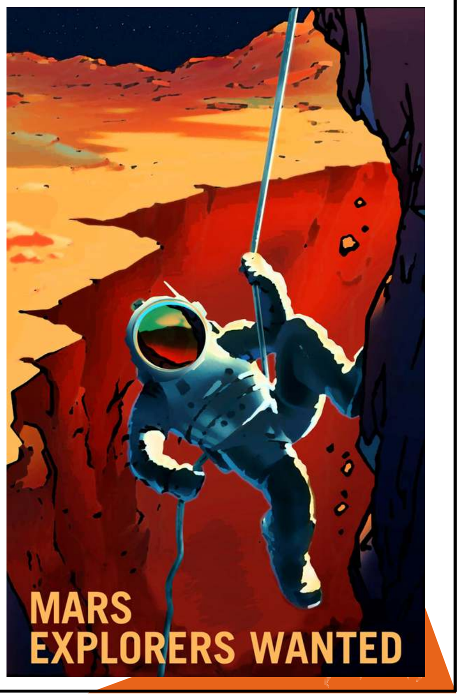
Most practical orbits will pass over most parts of the earth, giving satellites an excellent vantage point from which to take images.
These can be in the visible wavelengths (basically photos) but also in other frequencies which can allow data to be extracted regarding soil moisture, chlorophyll content, fish presence etc. Resolutions down to 50cm are commercially available.
Radar satellites can create elevation maps or track objects such as cars or ships.
Combining different sources allows services to be provided to agriculture, town planners, civil engineering projects, fishery industry, but also traders (how many cars are parked outside the shops, how much wheat will Russia grow this year).
Ultimately, few people want the images – it is the data which can be extracted from them which is of interest.



Satellites are used to inspect cloud cover, humidity levels, wind speeds, temperature profiles etc.

All of these are used both for operational meteorology (i.e. short to medium term forecasting) but also for monitoring of longer term trends and prediction.

MANNED SPACEFLIGHT



Manned spaceflight is today limited to flights to the international space station, using the Soyuz capsule for crew and various other capsules for cargo. In the near future, the US will start using their own crew transport.
At any time, 3-6 astronauts are on board the ISS, performing research tasks in microgravity for e.g. life sciences, metallurgy, astronomy etc.
There are plans for a transfer base around the moon as well as missions to Mars, realistically probably a decade away.

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SPACE INSURANCE

19

THE ROLE OF INSURANCE

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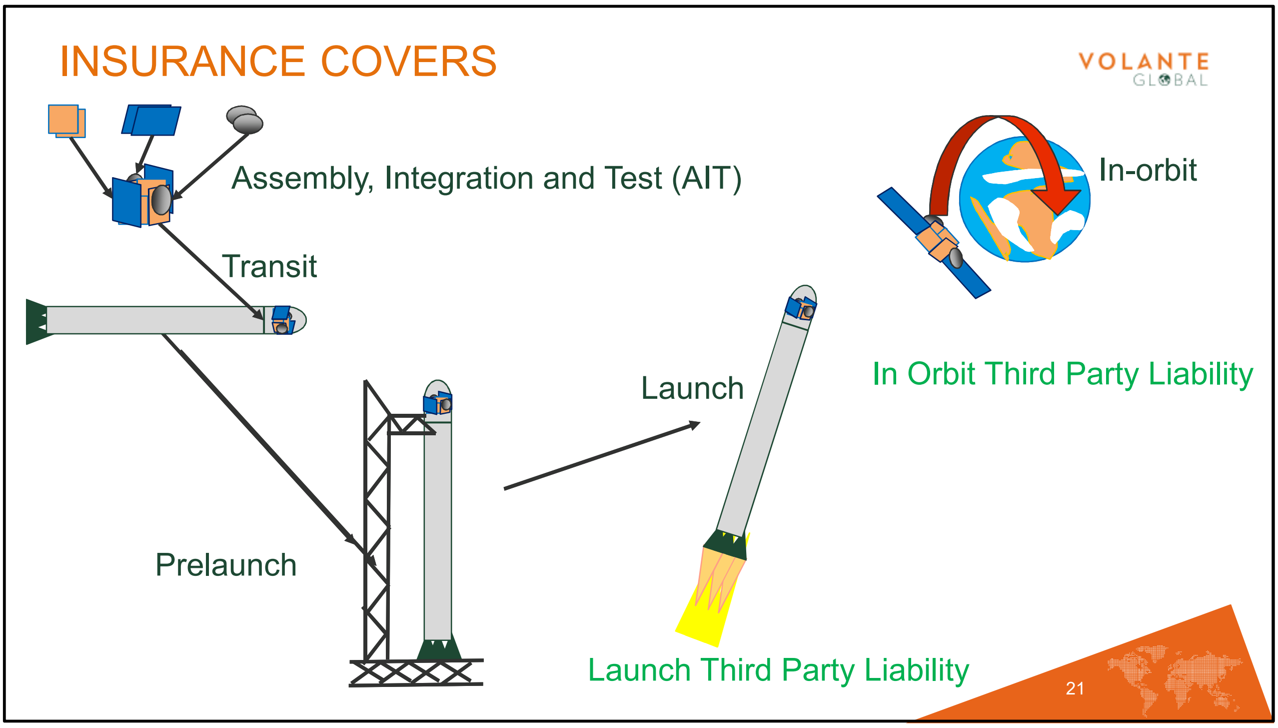
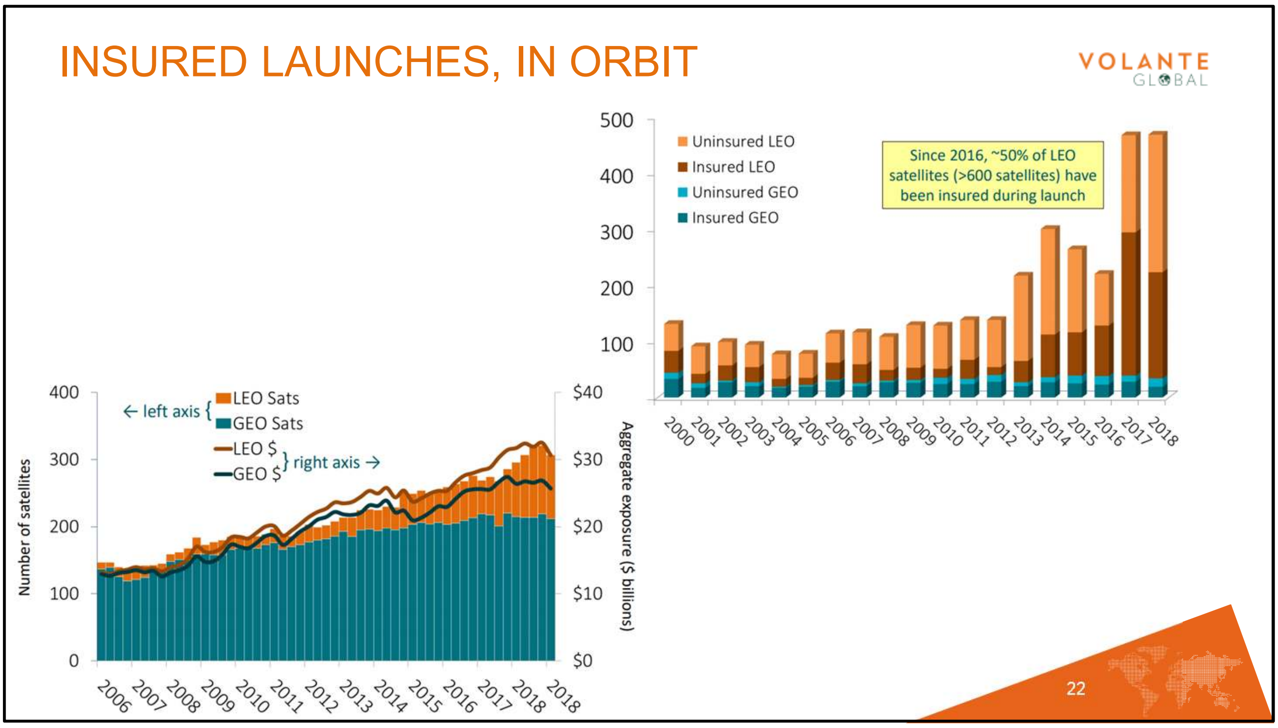
The role of insurance in space is the same as the role of insurance anywhere:

Insurance enables innovation and development by taking those risks which commercial enterprise cannot take themselves

Specifically, insurance enables innovators and entrepreneurs in the space sector to build a business plan which can be protected against many of the risks of technical performance (or lack hereof) of the high-tech equipment they will rely on.

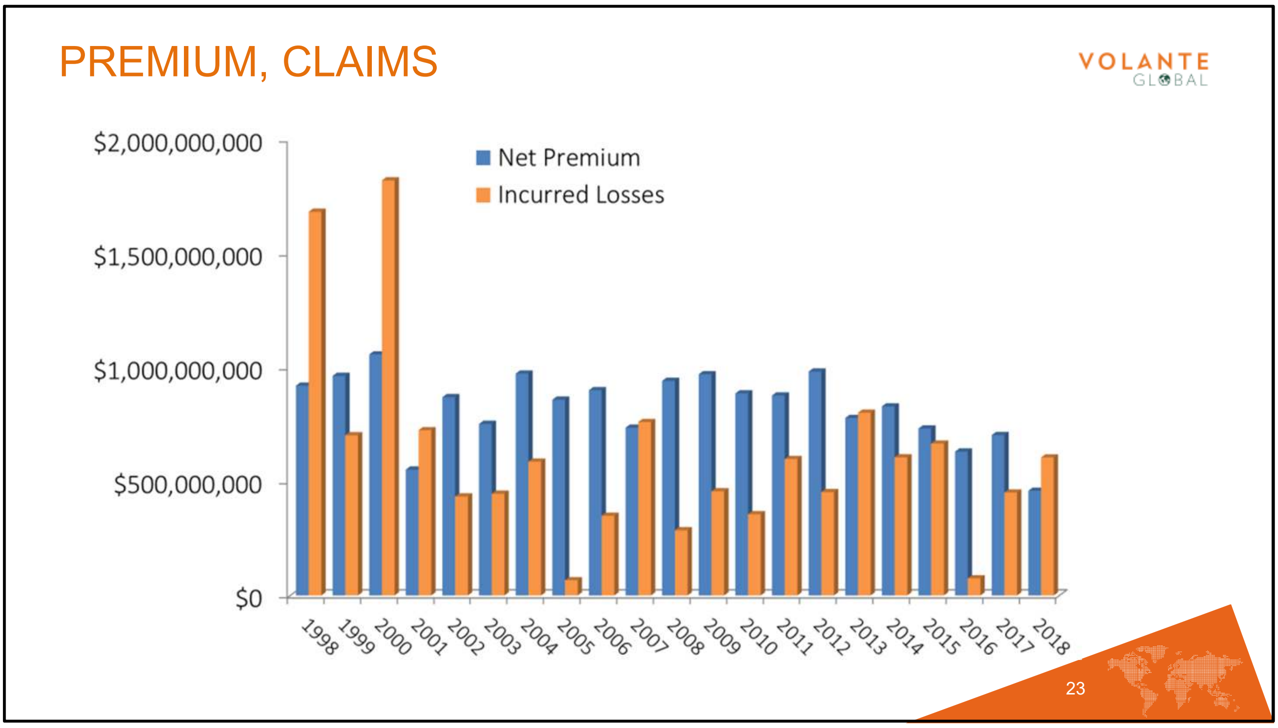


AIT and pre-launch is typically procured on an indemnity basis.
Launch and IO are agreed value based, using pre-agreed loss formulas to define the value of claims
TPL indemnity based
AIT and prelaunch typically written by the marine cargo market
TPL provided by aviation markets
Launch and IO provided by specilised space underwriters



There is both a general increase in the number of satellites launched and (therefore) the number of satellites in-orbit.
However, a recent trend is a change to smaller, cheaper satellites, which means that the total sum insured may not icrease even though the number of launches does increase. Technology development means that average satellites today can do what 4-5 satellites could do 10 years ago.

Global insurance premium is roughly 25% In-orbit, 75% Launch



The space market has been around since the early 90s when risks were few and rates were very high. Only very few markets and brokers were specialised in the segment, with most business being written by general aviation or marine underwriters.

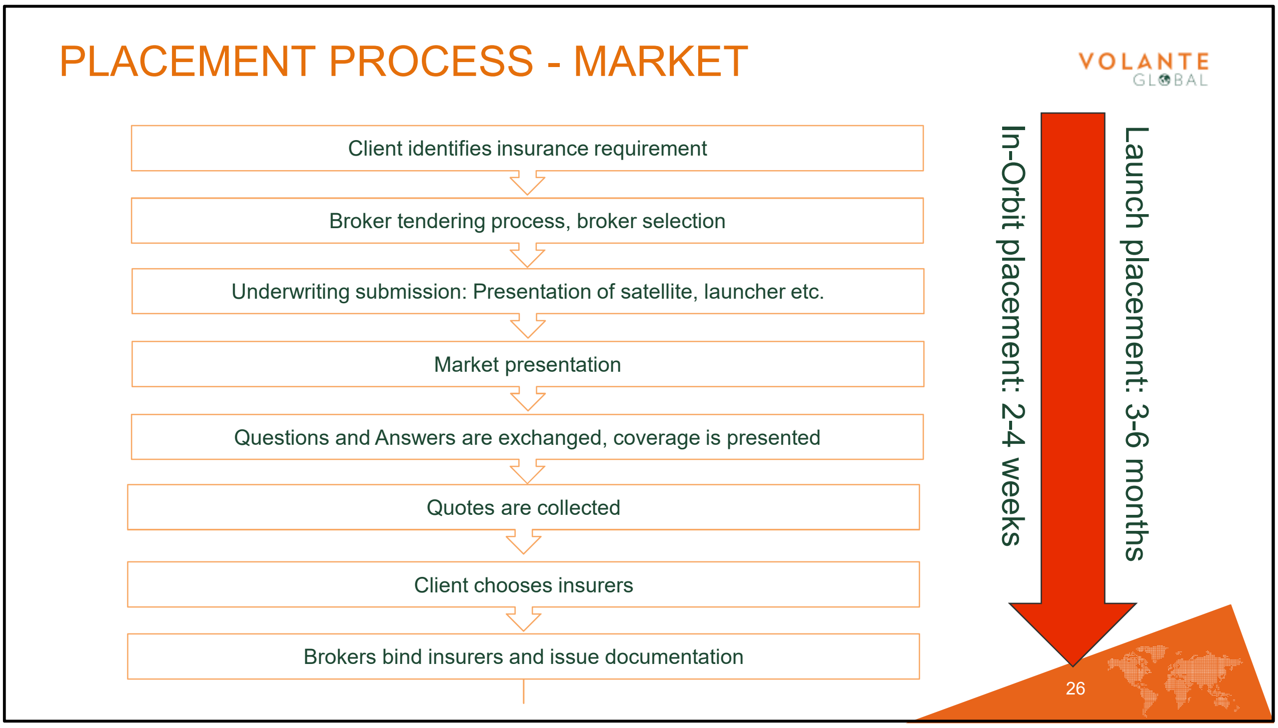
Since the end of the 1990s, specialist teams have been set up, both within brokers and insurers. Although space is still often grouped with Aviation, it has very few similarities or synergies.

Space is often referred to as volatile or as having a cat profile. This is not necessarily the case. Although a single launch loss will have a large impact on the year's result, the highest ever loss ratios in space are still 'only' in the mid to high 100%, not in multiples thereof. Against that, a good space year can see a 0% LR.

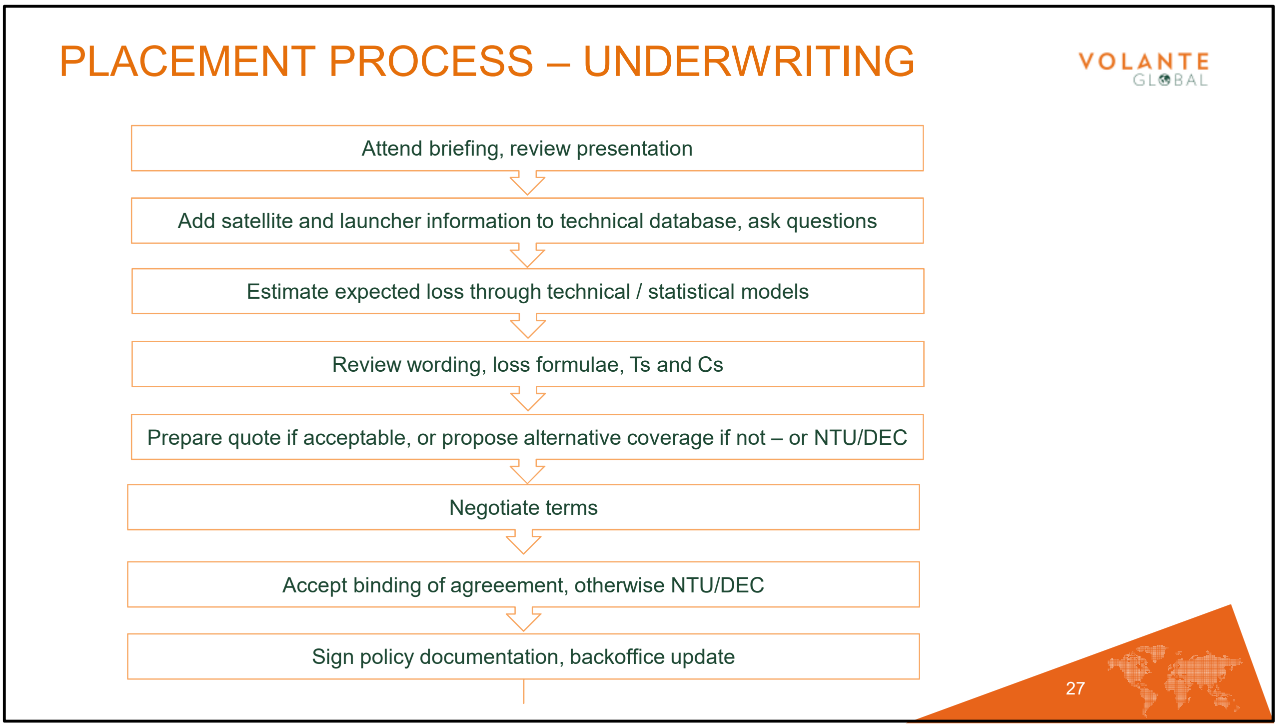
Good results for over 10 years since the early 2000s has lead a to very competitive rates in space until recently.

Almost all the space business is produced through brokers.
The traditional 3 big brokers share roughly a third of the market each, whilst Gallagher's (ex JLT) are trying to grow. Other brokers have some specalist accounts, e.g. UIB has close Russian links.

Most insurers write space from a single location; the market is a global market and an underwriter in e.g. London would see more than 90% of the global premium.
A typical team of 2-4 people has a mix of technical and underwriting experience, as well as wording and claims expertise.
The market is strictly verticalised, e.g. each insurer leads for their own share without knowledge of what other insurers offer.
A large amount of capacity (estimated around 50% of global) is offerd through MGAs.



Few insureds have insurance expertise, so the reliance on brokers is probaly more extensive than in other lines of business.
Brokers explain the coverages available and assist the insured to represent their business plan /risk scenarios through the loss formulas.
Brokers also assist the clients preparing NDAs, export license and not least the technical presentation.
Q and As can be in several rounds, as can quotes.
Wordings are normally issued based on broker standards; very few placements have insurer issued wordings.



The underwriting process is similar to other lines of business, although there is a higher level of technical assessment.

Most insurers will have a technical database of satellites design details and in-orbit events.

There are also some online databases available to provide additional details.

RISK ASSESSMENT LAUNCHERS - AMSAA

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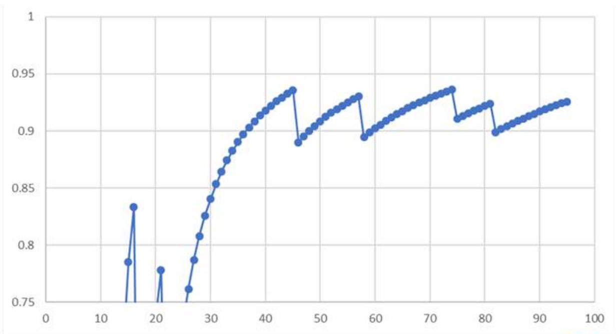
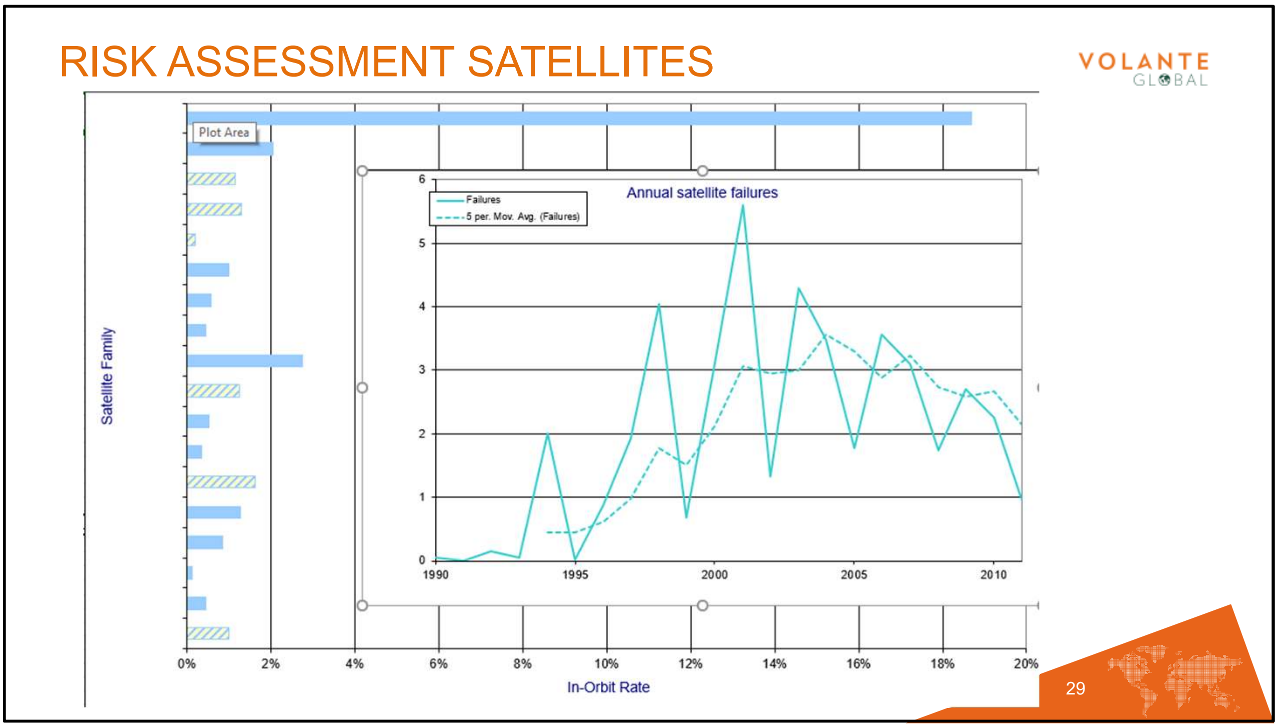
$$\lambda_i(T) = \lambda \beta T^{\beta-1}, \text{ with } T > 0,\ \lambda > 0 \text{ and } \beta > 0 \qquad \hat{\beta} = \frac{n}{n \ln T^* - \sum_{i=1}^{n} \ln T_i}$$



28

Assumes reliability growth. Assumes either /or results. Needs a failure to work. Is intended to model larger populations.
Launches are in theory perfectly repaired /redesigned before each next launch.
Applicability? Any better ways to obtain an estimated failure rate?



Few failures, difficult to have statistically representative samples. Most satellites are unique, so how relevant are other failures? Drilling down too much on specific satellite design features gives very small sample sizes.
So how to do it?

LOSS FORMULAS

- Transponder years:
  - Lifetime
  - Operating transponders
  - Beam interconnectivity
  - Bandwidth

$$PLA = \left(1 - Min\left[\left(\frac{AAcBOC}{SAcBOC}\right), \frac{APF}{SPF}\right]\right) \times AOI$$

Where –

Min	= 'Minimum of'
AAcBOC	= Actual Active Beam Operational Capability
SAcBOC	= Stated Active Beam Operational Capability
APF	= Actual Payload Flexibility
SPF	= Stated Payload Flexibility
AOI	= Amount of Insurance.

$$AAcBOC = \sum_{y=1}^{y=n} \sum_{AcB=1}^{AcB=x} BPI_b \times BW_b$$

Where:

y	=	Year within Satellite Mission Life being calculated
n	=	Final year of Satellite Mission Life
AcB	=	Active Beam being calculated
x	=	Total number of Fixed User Beams and Steerable User Beams that are Active Beams within year being calculated
BPI	=	Beam Performance Indicator
BW	=	Beam Weighting
b	=	Beam Identification Number

- Image collection capacity
  - Image quality (Resolution, SNR, MTF)
  - Image quantity
  - Agility
  - Storge and downlink ability

$$SPI = \frac{1}{ML} \times \left(\sum_{i=1}^{ML} ICQ_i\right)$$

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30

Loss formulas are intended to represent the loss to the insured should certain funcitionality of the satellite be lost.
Ideally, it translates those events which may occur on the satellite to a monetary value representing the loss to the insured.

The sum insured may be based on a replacement value (typically satellite price + launch price) or on a revenue estimate, or a combination of both. Some insureds use depreciating values, others do not.

CLAIMS PROCESS

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Event which the Insured believes may lead to a claim

30 days: Notice of event

180 days: Proof of loss

Questions and Answers

Potential Negotiations, Reassessment

Claim agreed

Settlement within 45 days

CLAIMS EXAMPLE – ARIANE 5 Maiden Flight

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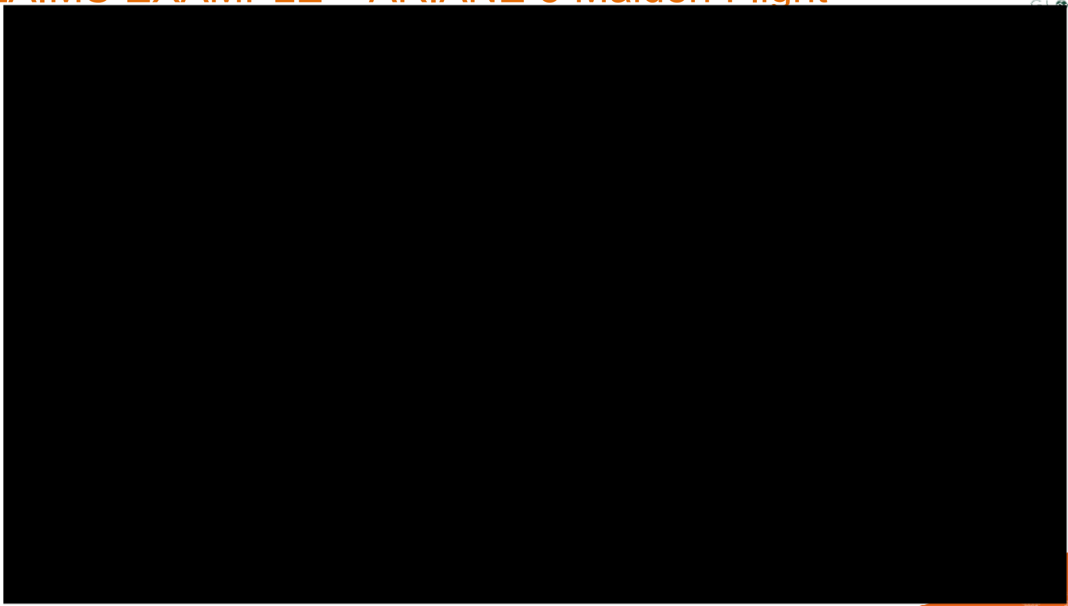
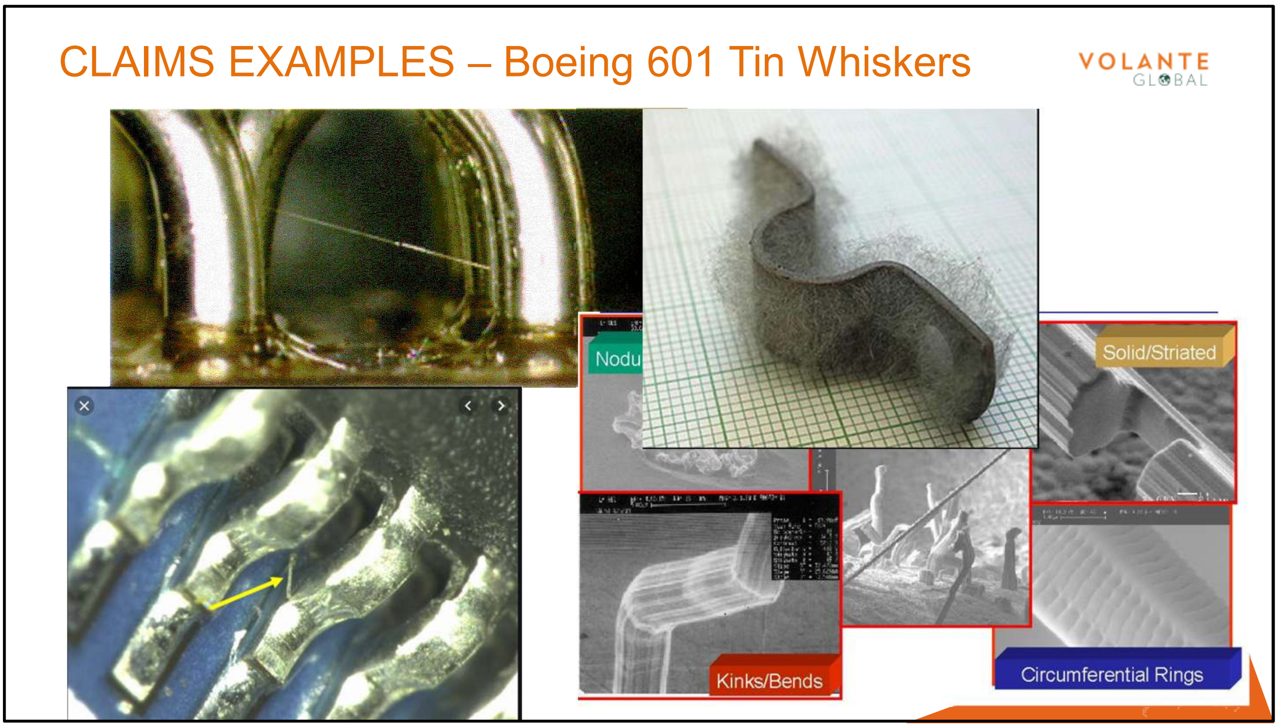


32

A software counter created an overflow and reset to zero.
The system declared itself to have failed.
The backup system had exactly the same issue.
Both systems were working perfectly but had declared themselves failed.
The on-board computer did not have valid data to control the launcher.
The launcher deviated from the planned trajectory, nozzles were commanded to full deflections.
The structure broke up due to aerodynamic stresses.
Failure report makes interesting reading at e.g. http://sunnyday.mit.edu/nasa-class/Ariane5-report.html



Lead used to be used for soldering as it makes soldering easier. However, lead is environmentally unfriendly and lead-free solder (pure tin) was used on some relays. Pure tin grows dendrites and whiskers. When 2 whiskers touch, they create a short circuit.

On the Boeing 601 satellites, these short circuits lead to the loss of one central computer, then the other... More than 12 SCPs were affected, losing at least 8 satellites out of 37 satellites launched.

Nowadays alternatives to pure tin, whilst still being lead free, are used.

E.g. https://nepp.nasa.gov/whisker/background/

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