The Mission

- Satellite Insurance Scenario
- International Space Treaties
- Launch Vehicles
- US Liability Regulations
- Insurance – Hull and Liability
- Space Hazards
- Manned Spaceflight

Space Basics

- Space – 100 km (Karmen Line)

  Accepted by the Fédération Aéronautique Internationale

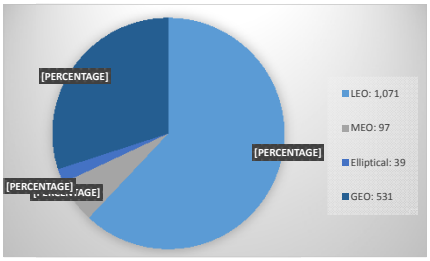
- Sub-Orbital
- Orbits

LEO (Low Earth Orbit):	160 – 2,000 km
MEO (Medium Earth Orbit):	2,000 – 35,400 km
GEO (Geosynchronous Earth Orbit):	35,786 km

GEO vs. NanoSat Comparison

	GEO	Nano
Satellite procurement agreement	Prime Co.	Anyone
Satellite Type	Standard bus	10 cm cube (3U, 6U)
Telemetry Tracking and Control	3 axis stabilized	none to minimal
Weight	1 to 5 tons	1 - 500 kg
Time to build and launch	1 - 4 years	1 mo. – 1 year
Launch Services Agreement	Prime	Secondary payload
In-Orbit Life	15 years	1 mo. – 5 years
Cost to Manufacture	$100-300 m	$50k - $20 m
Cost to Launch	$60 – $200 m	$10,000 – $5 m

Total Operating Satellites by Orbit: 1,738



Data as of 8/2017

SATELLITE BOX SCORE

(as of 04 January 2018, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads*	Rocket Bodies & Debris	Total
CHINA	269	3594	3863
CIS	1515	5003	6518
ESA	81	56	137
FRANCE	63	483	546
INDIA	85	115	200
JAPAN	170	100	270
USA	1634	4687	6321
OTHER	866	114	980
TOTAL	4683	14152	18835

* active and defunct

Outer Space Treaty - 1967

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.

Article IV – Peaceful Purposes

Article VI – States are directly responsible for all their national space activities

"If you read the Outer Space Treaty, it says basically don't bring anything back that kills humanity." Len Fisk, President of COSPAR

Astronaut Agreement - 1968

Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space

Liability Convention - 1972

Convention on International Liability for Damage Caused by Space Objects

- Imposes absolute liability on the Launching State for damage caused on the surface of the Earth or to aircraft in flight.
- Liability for damage occurring elsewhere including space is fault based.
- Launching State is the state that launches or procures the launch of a space object or from whose territory a space object is launched.

Registration Convention - 1975

Convention on the Registration of Objects Launched into Outer Space

- Each Launching State shall maintain a registry of all space objects and inform the Secretary-General of the United Nations.

Moon Agreement - 1979

Agreement Governing the Activities of States on the Moon and other Celestial Bodies

- Concerns the exploitation of resources from outer space.
- Not well supported

1979 Export Administration Act; International Traffic in Arms Regulations (ITAR)

- Regulation controls the export and import of defense related articles and services on the US Munitions List (USML)
- ITAR Compliance requires registering with the US State Department's Directorate of Defense Trade Controls (DDTC)
  Applicable to
  - Manufacturing process
  - License requirements including launch data/profile
  - The launch platform/vehicle
  - Satellites or other payloads
- Negative effects on the US Satellite industry

Launch Vehicles

- Growing Number of Options
  - ELV – Expendable Launch Vehicle
  - RLV – Reusable Launch Vehicle
  - ISS – International Space Station
  - Hybrid – Captive-carry air launched Launch Vehicle

1984 – Commercial Space Launch Act (CSLA)

- Requires all launch vehicles and launch sites to be licensed
- Allows for use of government property and services
- Insurance required in an amount determined by the Secretary considering international obligations
- One Launch Liability policy covers the launch participants (flow down)
- Reciprocal or Cross-Waivers of Claims

1988 – CSLA Amendments

New Liability Insurance Requirements - Three Tiered Approach:

I: Maximum Probable Loss (MPL)-. Amount capped at $500 million ($100 million for Gov't property).

II: Catastrophic Loss Protection (Government Indemnification Congress may appropriate up to an additional $1.5 billion (adjusted for inflation: $3.2 B).

III: Above MPL-Based Insurance + Indemnification. Financial responsibility remains with the licensee, or legally liable party.

1994 –National Space Transportation Policy/ NASA Act

- DOT – Dept. of Transportation with NASA could not offer indemnification.
- Congress granted NASA third-party liability indemnification authority.
- Like CSLA - Law required insurance based on MPL (maximum probable loss), cross waivers of claims with NASA, the vehicle developer, contractors and subcontractors.
- If insurance reasonably unavailable, NASA authorized to provide liability insurance for a vehicle developer.

1997 – International Space Station (IGA)

- Cooperation on the ISS between the Governments of Canada, Member States of the European Space Agency, Japan, The Russian Federation and the United States of America
- Article 16 – Cross-Waiver of Liability by Partner States: Each Partner State waives all claims against any entities listed based on damage arising out of Protected Space Operations whatever the legal basis (includes Liability Convention) exceptions – waiver not apply to:
  - Natural person for bodily injury
  - Claims for damage caused by willful misconduct

1998 – Commercial Space Act- PL 105-303

- Grant authority to the FAA to license the return of vehicles from space to Earth and extended the risk sharing regime for licensed reentry vehicle operators.
- Reentry defined as when the vehicle is prepared specifically for reentry or when reentry is intentionally initiated or when the vehicle's attitude is oriented for propulsion firing to place the vehicle on its reentry trajectory.
- On-orbit activities fall outside the bounds of the law.

Satellite Insurance Placement

- Who Needs Insurance?
- GEO – Traditional Coverage
- Constellation Coverage – Tailored
- In-Transit and Pre-Launch
- Launch Coverage
- In-Orbit Coverage

Traditional Space Insurance

- Full briefings 2 or more years prior to launch
  - Satellite contracts
  - Specifications and mission
  - Launch Vehicle services agreement
- Insurance policy conforms to satellite contracts
- Total loss and unique partial loss coverage drafted
- Insured Value – sum of costs to:
  - Manufacture
  - Launch
  - Insure

Traditional Space Insurance

- Policy Issued – 3 year period – on risk at "Launch"
- Risk Period - LVFO (Launch Vehicle Flight Only), Launch plus 1 or more years then Annual periods thereafter
- Follow up briefings prior launch
- Premium – 5% deposit, full payment 30 days prior to launch

Space Insurance – LEO Constellation

- Why Buy Insurance?
- Insurability
- Spread of Risk in large numbers
  - Planet – 191 satellites
    - 88 Doves launched on a single Indian PSLV (Feb 2017)
    - VEGA, DEPNR, ISS Nanorack (ISS), Soyuz (48)
  - Iridium – 83 satellites
    - NEXT (block 2) 10 s/c per launch

Cosmic Hazards

- Space Debris
- Solar Flares and Coronal Mass Ejections
- Near Earth Objects
- Biological Hazards

Orbital Debris

- Since 1957 with launch of Sputnik
- 22,000 pieces of debris larger that 5 cm tracked
- 300,000 pieces the size of a marble
- LEO has highest density (45%)
- Kessler Syndrome – collisions between objects could cascade with each collision generating orbital debris, which increases the likelihood of further collisions

Orbital Debris Occurrences

- 2009 – Iridium 33 and Cosmos 2251, Collision at 789 km.
- 2007 – Chinese missile test on FY-1C at altitude of 865 km. Largest recorded event 150,000 particles / 2,500 trackable.
- 2003 – Spaced Shuttle Columbia – 80,000 fragments
- 2001 – Mir Space Station – 130,000kg / 1,500 fragments
- 1985 – US ASAT destroyed Solwind 555 km / 285 trackable
- 1979 – Skylab – 70,000 kg station
- 1963 - US anti-satellite missile test (ASAT) destroyed satellite

Solar Flares and Coronal Mass Ejections

- 2003 Halloween Storm, CME traveled to earth in 19 hours. Sweden lost power, 28 s/c damaged, 2 destroyed
- 1989 Montreal Event, Canadian Hydro-Quebec power grid brought down in 2 minutes. 6 million lost power, $12.7 Billion in losses
- 1859 Carrington Event, CME traved to earth in 17 hours. Fires in telegraph offices, Auroras bright enough to read by. Similar storm today cause over $2 trillion in damages.

Near Earth Objects

- Comets, Asteroids, Meteors, Meteorites and Bolides
- 2013 – Chelyabinsk, Russia, 18 m diameter meteor exploded over city. 1,600 injuries / $30 million estimated losses
- 1908 – Tunguska, Russia, 50 m diameter comet or asteroid burst over uninhabited area leveling trees over 2,000 km square.
- 65 million years ago – Yucatan Peninsula (Chicxulub), 6 km diameter asteroid caused worldwide climate change led to extinction of 70% of all species on earth.

Commercial Space Launch Amendments Act 2004 (CSLAA)

- Amendments directed at Manned Suborbital Rockets
- CREW and SPACE FLIGHT PARTICIPANTS (SFPs) defined
- Crew: Requires Class II Medical and specifies Training requirements
- SFPs: After 3 years FAA may create training and medical standards
- FAA can't create vehicle standards for 8 years. The certification of launch vehicles would be overly burdensome and costly
- Operators are certified via license not the vehicle

CSLAA – Defined Suborbital Rocket

- Suborbital Rocket means a vehicle, rocket propelled in whole or in part, intended for flight on a suborbital trajectory, and the thrust of which is greater than its lift for the majority of the rocket-powered portion of its ascent.
- The definition stands for 3 years. After 3 years the FAA can redefine what constitutes a "suborbital rocket" in order to cover all appropriate vehicles.

CSLAA – Reciprocal Waiver of Claims

- Crew are employees and only recourse against employer is willful misconduct
- Entities will need to protect themselves from SFPs.
- SFPs are not covered by claims eligible for indemnification under CSLA.
- SFPs may want mutual waiver of claims agreements with operator so the operator can't come after him for damage to the vehicle. Even if not required by statute, it may be in the best interest of all to enter reciprocal agreements.

CSLAA – Informed Consent

- Mandates a regulatory regime premised on the right of participants to assume informed risk and focuses chiefly on protecting the safety of the uninvolved public.
- Requires Informed Consent
- Both Flight Crew and SFPs are advised
  1) the U.S. Government has not certified the launch vehicle as safe for carrying flight crew or SFPs.
  2) Reciprocal Waiver of Claims with the DOT/FAA.

CSLAA – Informed Consent

Informing SFP of the Risks in writing from SRLV (sub-orbital reusable launch vehicle) operator about the risks of launch and reentry, include:

- The safety record of the specific SRLV
- Include the likelihood and consequences of any reasonably foreseeable hazardous event
- Inform SFP that the space flight may result in his or her death, serious injury, disability, and total or partial loss of physical and mental function.

CSLAA – Informed Consent

- Describe to SFP the safety record of all launch or reentry vehicles that have carried one or more persons on board including both U.S. government and private sector vehicles.
- Written Informed Consent and Compliance signed by the SFP. Should not relieve the SRLV operator of responsibility for gross negligence.
- SFPs provide written certification of compliance with a physical exam.

NASA Aerospace Safety Advisory Panel

Annual Report 2017

Probabilistic Risk Assessment for Loss-of-Crew

"The CCP PRA requirement for LOC covering a 210-day mission to ISS is 1 in 270"

Three measures of the risk:

- CCP Transportation Systems (1 in 200)
- Ascent and Entry Mission Phase (1 in 500)
- Orbital/Docked Phase

Risk Drivers:

- MMOD damage during docked phase (affects mission)
- Parachute performance (affects mission/ascent-entry)

ASAP Probabilistic Risk Assessment for Loss-of-Crew

"The Aerospace Safety Advisory Panel has been monitoring the providers' progress in working toward the Loss-Of-Crew requirements, and it appears that neither provider will achieve 1 in 500 for ascent/entry and will be challenged to meet the overall mission requirement of 1 in 200 (without operational mitigations)."

"The likelihood remains that the providers will not meet all the PRA requirements, and NASA will need to determine if the risk portrayed by the analysis, with its large uncertainties, is acceptable."

NASA Aerospace Safety Advisory Panel

- "Micrometeoroids and Orbital Debris (MMOD) has become recognized as a major issue in every program. Damage from MMOD is the dominant contributor to the calculations of loss-of-crew (LOC) predictions for both commercial crew vehicles as well as Orion, and to two of the top three safety risks for the International Space Station (ISS)."
- International Space Station: "NASA estimates that the probability of a need to evacuate the Station is approximately 1/60 per year, or a 12 percent chance during the 7 remaining years of projected Station life. This increases proportionally if Station life is extended."

Optimist

"By the year 2600, the world's population would be standing shoulder to shoulder, and the electricity consumption would make the Earth glow red-hot. This is untenable. But I am an optimist. I believe we can avoid this potential for Armageddon, and the best way for us to do this is to move out into space and explore the potential for humans to live on other planets."

Stephen Hawking, at the Tencent WE Summit in Beijing 11/8/17.