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IIPE MANUFACTURING NEWS

Editor-in-chief
Dr. K. Gopalakrishnan

Monthly Newsletter of the Indian Institution of Production Engineers

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HISTORICAL ACHIEVEMENT

The Indian Institution of Production Engineers (IIPE) has signed MoU with World Confederation of Productivity Sciences (WCPS) on 24.01.2019

*IIPE has been represented by its Chairman **Padmashri Prof. R. M. Vasagam** and National Secretary, **Dr. K. Gopalakrishnan** and WCPS has represented by **Mr. John Heap,** President, WCPS and **Mr. Peter Watkins**, President, WNPO during the Signing of MoU.*

Students Mini-Project Exhibition

K. K. WAGH INSTITUTE OF ENGINEERING EDUCATION AND RESEARCH, NASHIK DEPARTMENT OF PRODUCTION ENGINEERING

Along with theory concept, industries also need to know capacity of students to complete projects using their specific initiatives. Mini projects for engineering students gives an edge over the race of recruitment to ensure a good career. In view of employment practices in recent times, students are progressively taking up mini-projects to pad up their skill-set and to gain practical knowledge. Department of Production Engineering therefore organized the mini project competition for SE, TE and BE Production Engineering students in association with IIPE, Nashik local chapter on 13th October 2018. About 70 students participated in this competition. Students prepared the mini project on various topics such as Jigs and Fixture design, portable mini wooden lathe machine, Model of progressive die design, bearing bracket for rotating shaft etc. Prof. S. S. Sane, Dean (Administration), KKWIEER visited the exhibition of mini projects by students. He appreciated the efforts of students and gave some valuable suggestions for improvement.

Students demonstrating the mini project: along with students from left Prof. P. J. Pawar, HOD, Production Engineering, Prof. S. S. Sane, Dean (Administration), KKWIEER, Dr. N. B. Gurule, Associate Professor, Department of Production Engg.

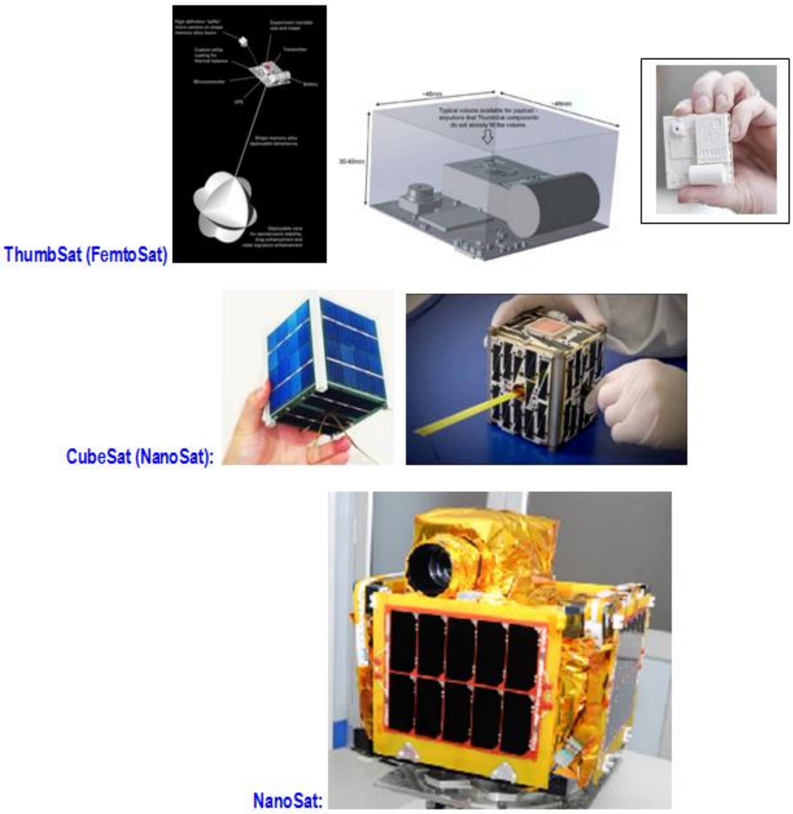
News Item Courtesy: *Dr.K. N. Nandurkar (PhD IITB), Principal, K.K.Wagh Institute of Engineering Education & Research, Panchavati, Nashik-422003*

Era of Small Satellites: Pico, Nano and Micro Satellites (PNM Sat)-An Over View

Dr. K. Gopalakrishnan,
National Secretary, Indian Institution of Production Engineers (IIPE) and Convener, 75 Students' Satellites Consortium: Mission 2022
Dean (R&D), New Horizon College of Engineering, Bangalore

ACRONYMS AND ABBREVIATIONS

Al Aluminium
AA Aluminium alloy
AOCS Attitude and orbit control subsystem
ASD Acceleration spectral density
ATOX Atomic oxygen
CAD Computer-aided design
COM Communication subsystem
CoG Center of gravity
CoM Center of mass
EO Earth observation
EPS Electric power subsystem
E-sail Electric solar wind sail
EMC Electromagnetic compatibility
ESD Electrostatic discharge
EM Engineering model
ESA European Space Agency
FEA Finite element analysis
FPGA Field-programmable gate array
FH Flight hardware
GEO Geosynchronous orbit
CG Gold gas
HW Hardware
HS High-level sine
HSCOM High-speed communication
IFA Inverted-F antenna
LV Launch vehicle
LEO Low Earth orbit
MoS Margin of safety
MEO Medium Earth orbit
OBCS On-board computer subsystem
PSD Power spectral density
PCB Printed circuit board
PDF Probability density function
PNMSat PicoSat, NanoSat and Micro Sat
PR Public relations
RF Radio frequency
RW Reaction wheel
SDOF Single-degree-of freedom
SPL Sound pressure level
SS Stainless steel
ST Star tracker
STR Structure subsystem
Ti Titanium
UHF Ultra-high frequency
VHF Very high frequency



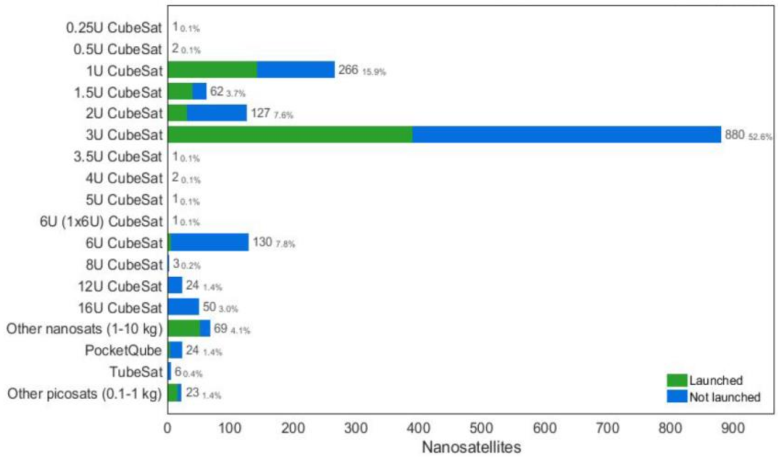


Figure 1 Nanosatellites by type

CubeSat *concept introduced by Bob Twiggs and Jordi Puig-Suari in 1999*

- *small (10x10x10 cm, 1 kg – Picosatellite)*
- *low cost*
- *short development time*
- *ideal for education*
- *involvement in all phases of Space project*

Nanosatellites (NanoSat)

- *First CubeSats launched in early 2000*
- *By now: > 800 nanosatellites launched*
- *Record in 2017: 104 on a single PSLV launcher*
- *Exponential increase in recent years*
- *Standard deployers important*
- *XPOD, P-POD, ISIPOD, Nanoracks (from ISS)*
- *Standardized launcher interfaces*
- *Initially mostly 1U, 2U, 3U CubeSats*
- *Trend to larger nanosatellites 6U, 8U, 12U*
- *Nanosatellite classification 1…10 kg mass*

Introduction

The first man-made object that was launched into space was the Sputnik-1 satellite [1] in 1957. That was fascinating and charmful for all humankind and escalated the Space Race [2], consequently developing technologies and bringing attention to space science around the globe. Space become more accessible and open not just for governmental space agencies and huge companies, but for universities and other educational institutions in recent years. Technologies and devices have a tendency of becoming smaller in size and more powerful in performance (an ideal example is the Smartphone industry). A similar development has occurred in small satellite design, they have decreased in size as well as becoming more standard in their build-up. This trend was introduced by the California Polytechnic State University and Stanford University as CubeSat in 1999.

Cube Satellite (CubeSat)

It is a cubic-shape satellite identified by the number of units. One unit, more commonly known as 1U, is a cube with a volume equivalent to the one litre and a side-length of 10 cm. By merging a few cubes on top of each other, the variety of sizes increases (1U, 2U, 3U, 6U…). Satellites can be categorised by their mass. The one with a mass below 1 kg is a picosatellite, which is very often a 1U CubeSat (by default the mass of each unit should not exceed 1.33 kg), or a PocketQube (0.25U). The majority of launched or built CubeSats consist of nanosatellites with a mass of 1-10 kg, shown in Figure 1, as per March 14th 2017 [3].

Majority of 3U CubeSats mentioned in Figure 1, below, with a nominal mass limitation equivalent to 4 kg, however depending on the deployer (mechanical interface between the CubeSat and the launch vehicle (LV)) the mass can be higher. As in the case of ISIPOD, the maximum allowable mass for 3U is 6 kg [4]. A spacecraft with a mass range from 10 to 100 kg is a microsatellite, below 1 kg a picosatellite, and below 0.1 kg a femtosatellite. The smallest publicly-known femtosatellite is KickSat, a 3.5 by 3.5 cm single printed circuit board (PCB) with microprocessor, gyroscope, magnetometer, radio with antennas, and solar cells [5].

As with any piece of hardware (HW), a satellite needs a structure for holding it together or deploying into the orbit as per case of KickSat. Moreover, the development process for space structures is somewhat similar to the ground-application one with much more strict requirements and constraints.

Development process initiates with the list of requirements and ends up with the product delivering for LV integration; it consists of designing, verification, manufacturing, and testing. Design means developing requirements, identifying options, doing analysis and trade studies, and defining a product in enough detail so one can build it [7, p.1]. For the ground applications, one also considers the outer look (how it looks like and how it feels like), however, for the space mission the main target in designing is functionality under certain requirements (some exceptions exists for public relations (PR) purposes). Hence, the structure has to be cost-effective which means obtaining high performance, reliability, and confidence for spent money, considering not only knowns but also variables and uncertainties [7, p.1].

In the particular case the satellite consists of payloads (which conduct scientific and technologic demonstration and performance) and subsystems or satellite bus (which operates the spacecraft). The structure supports the payload and spacecraft subsystems with enough strength and stiffness to preclude any failure (rupture, collapse, or detrimental deformation) that may keep them from working successfully [7, p.23]. Key requirements consist of functional (what must be done), operational (how well it must be done), and constraints (limit the available sources, schedule, or physical characteristics) [7, p.26]. The risk has to be evaluated and if the elimination is not feasible due to constraints in terms of time, cost, or schedule shift, than one has to accept the certain probability of failure or damage. In addition, the level of risk has to be evaluated with its influence on the entire mission – will it cause full mission failure or just minor element deformation that does not affect the mission success. Any risk evaluation starts with the estimation of failure probability and resolving consequence of that failure.

Space Mission Habitat

After the satellite reaches required orbit it will be exposed to other harmful habitats in the near-Earth space environment. The list consists of, but is not limited to, vacuum, thermal radiation, charged-particles radiation, neutral atomic and molecular particles, micrometeorites and space debris, magnetic fields, and gravitational fields [7, p.61]. Various sources are influencing the man-made objects as a function of orbit (Figure 2), where LEO is a low Earth orbit (160-2000 km), MEO is a medium Earth orbit (2000-35000 km), and GEO is a geosynchronous orbit (35876 km).

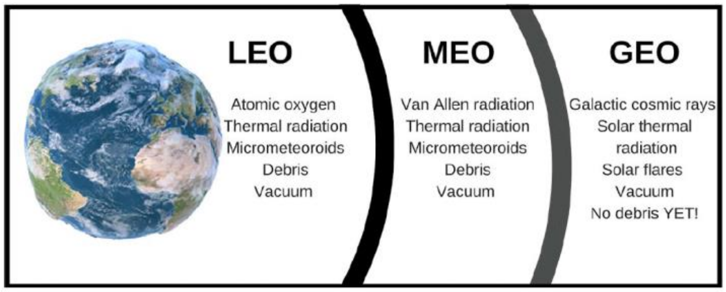


Figure 2. Space environment as the function of altitude

The term **vacuum** describes extremely low pressure in space. A vacuum has various effects on the structure. In vacuum, polymer-based materials (thermal insulators, adhesives, and the matrices for advanced composites) release substances in a gaseous form [7, p.63]. The substance is one of an organic origin or absorbed nitrogen, oxygen, and carbon dioxide on the ground. Moreover, the material has issues with water desorption that was absorbed by the material during on-ground processes. The aforementioned effects may degrade certain properties of material and might cause condensation on critical surfaces (lenses, mirrors, and sensors). Another effect is the internal pressure of sealed structures that was assembled at the ambient Earth pressure.

Thermal radiation is mainly a reference to direct solar flux (1309-1400 W/m^2) which means intensity of radiation, planetary albedo (global annual average is 0.3) which originates from the reflected solar flux, planetary emission flux (189-262 W/m^2), and the satellite electronics' infrared thermal emission. This results in a nonuniform heating of spacecraft which causes materials (especially with various thermal expansion coefficients) to expand differently, resulting in structural stresses. In addition, certain components require a precise operation temperature range (e.g. batteries, propellant tanks). The solution is to implement an active (requires power) and/or a passive (materials and coatings) thermal control system.

Charged-particle radiation is a high flux of energetic particles. The major sources are *trapped radiation* (Van Allen belt) which contains electrons and protons in the MEO, *galactic cosmic radiation* which contains 90% of protons and 10% of helium nuclei in the GEO and further, and solar radiation which is largely continuous solar wind (electrons, protons, and helium nuclei low in energy) and solar flares (high energetic protons and heavy ions) [7, p.69]. The radiation has a negative effect on the electronics and may cause damages or failure. There is no way to predict or to be protected against galactic cosmic radiation, thus electronics have to tolerate it.

Classification/Category of Satellites (Based on Weight)

a) Minisatellite (100–500 kg)
b) Microsatellite (10–100 kg)
c) Nanosatellites (1 -10 kg)
d) Picosatellites (100 gm-1 kg)
e) Femtosatellites (10-100 gm)

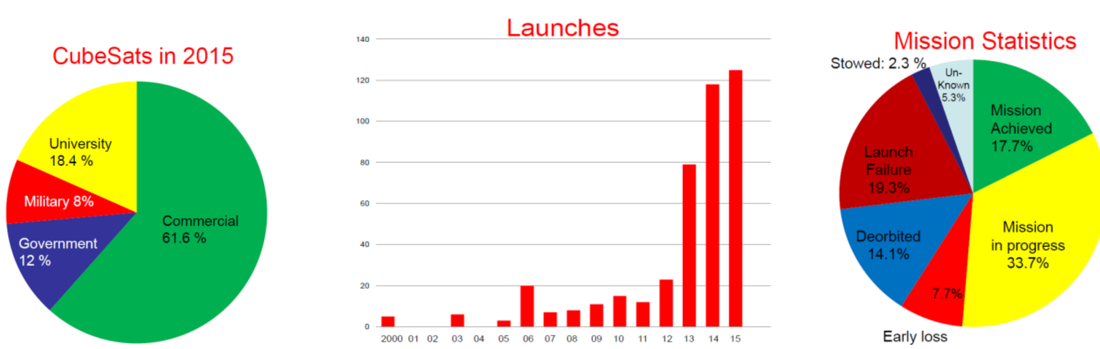


Figure 3. NanoSats Launched till 2015 *Source: M.Swartwout*

Against trapped and solar radiations, shieldings are implemented. The structure of the satellite can act as a radiation shield as well. For instance, in order to keep the total radiation dose below 10e4 rads per year at 4000 km, the required thickness of aluminium is 9 mm [7, p.71].

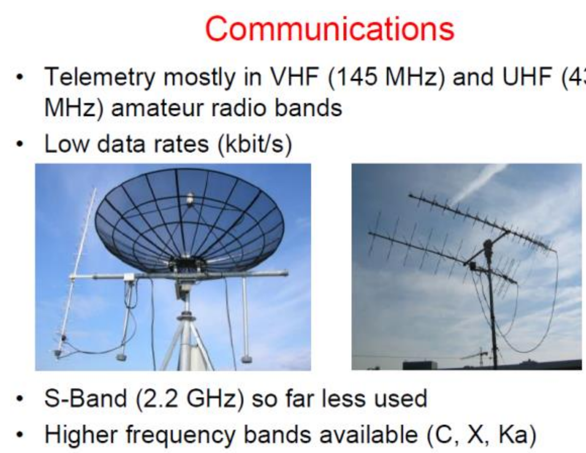
Space Debris

- *Increasing number of nanosatellites imposes a space debris risk*
- *LEO orbit crowded*
- *Orbit to comply with < 25 year orbital life-time*
- *Or: Active De-orbiting Mechanisms*
  - *Deployable sails/structures*
  - *Drag mechanisms*
  - *Propulsion (e.g. micro arc-jets)*

LEO contains relatively stable atomic and molecular particles. When the spacecraft moves at orbital hypervelocity, its surface is struck by particles that cause material recession. The most damaging is atomic oxygen (ATOX) [8]; among other impactors are N_2, O_2, *Ar, He, H*. The erosion process and rates rely on the material's composition. The most damaging are polymer based materials, while the impact on metals is not that significant, especially on aluminium (Al) which is commonly used for space structures due to its low density, radiation shielding capabilities, and manufacturability. For instance, an exposed Al surface to ATOX at an altitude of 500 km has an erosion rate of 7.6e-6 mm/year, however the same parameters applied to silver results in the erosion rate of 0.22 mm/year [9].

Micrometeoroids and Space Debris can have a fatal impact on the spacecraft structure at the orbital hypervelocity due to impacts (if the size of impactor is large enough). One can implement shielding against smaller objects. In addition, thermal blankets decrease the impact of small objects [10, p.10-11].

The **plasma brake** (Figure 4a) is an end-of-life disposal technique for objects in the LEO. The infamous space debris issue was regulated with a limit in the orbital post-mission lifetime of 25 years or 30 years after launch for all satellites in the LEO [11]. The problems behind already existing debris are upcoming large constellations shown in Figure 4b. The probable collisions at orbital hypervelocities (over 3 km/s) will cause defragmentation which will consequently result in an enormous escalation of small objects, better known as the Kessler syndrome, which will disable access to LEO if the escalated problem is ignored.



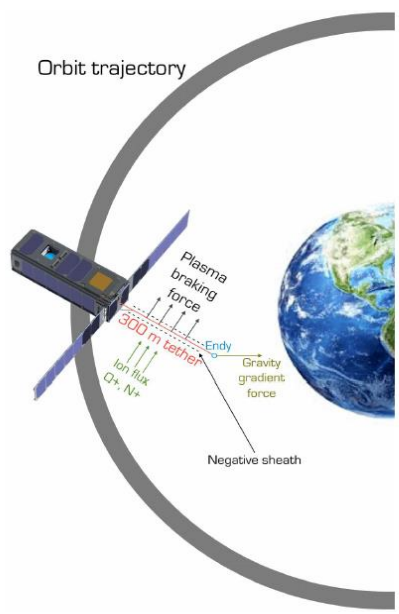


Figure 4a. Plasma brake concept for the gravity-stabilised tether

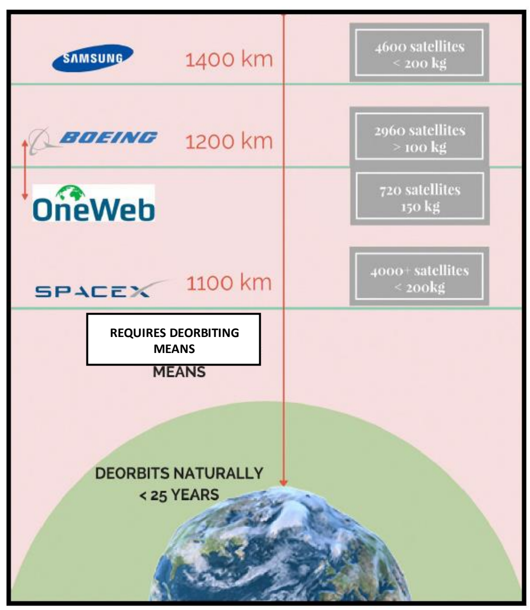


Figure 4b. Upcoming large constellations

Space Missions with Few Examples

- Astrobiology
- Astronomy
  - BRITE
  - CANIVAL-X (NASA): formation flying, virtual telescope
- Atmospheric Science
- Biology
- Pharmaceutical Research
- Earth Observation
  - Planet Labs (commercial)
- Space Weather
- Telecommunications
  - AIS (UTIAS, SPIRE- commercial)
  - ADS-B monitoring
  - Messaging
  - Amateur Radio
- Material Science
- Technology (OPS-SAT)

Work Group	***Major Team/Core Activities***
Antenna Systems	*Selection of Payload (Novelty)*
Attitude Control Systems	
Communication Systems	
Command Data Handling Systems	
CubeSat Structures	
Solar Panels	
CubeSat Platforms	*Payload Design and Development*
Payload Identification/Development	
System Integration	*Payload Integration*
Software Programming	*Mission Software Development (Programming)*
Launch Service	*Launch Logistics*
Ground Control Station	*GCS*
Commissioning and Operations Support	*Observation*
Review of Literature/Case Studies	*Documentation*
Testing and Analysis/ Failure Analysis	*System-Level Testing*

Major Components of Satellite Programmes

Space: Antenna systems, Attitude Control Systems, Communication Systems, Command Data Handling Systems, CubeSat Structures, Solar Panels,
Launch: CubeSat Deployers,
Ground: Ground Stations, Ground Support Equipment, Generic Engineering Model

a) Size & Objectives : CubeSat and Nanosat/Picosat Missions
b) CubeSat Platforms
c) Payload Development and Integration
d) Launch Services
e) Ground Stations
f) Commissioning and Operations Support

Lead Agencies:

Israel: *The Herzliya Science Center and Tel Aviv University*

India: *Indian Technology Congress Association*

Supporting Agencies:

1. *Indian Space research Organization , ISRO*
2. *Israel Space Agency and Israel Aerospace Industry*
3. *French National Space Research Center, CNES*
4. *United Nations Space Office – UNOOSA*
5. *World Federation of Engineering Organizations (WFEO)-ICT*
6. *BRICS Federation of Engineering Organisations*
7. *World Academy of Engineers*
8. *CANEUS Small Satellite Sector Consortium, Canada/USA*
9. *University Space Engineering Consortium (UNISEC)–Global, Japan*

APPLICATIONS:

ISISpace has been working on training next generation scientists and engineers, performing small scale science missions or planning a novel application using a globe-spanning constellation etc.

Potential space applications are listed below *(but not limited to the following)*:

1. ***Earth Sciences:*** *Nanosatellites for better understanding of our own planet*
2. ***Ship Tracking Services:*** *Near real time vessel tracking using satellite-AIS*
3. ***Aircraft Tracking:*** *Keeping track of aircraft on a global scale using ADS-B*
4. ***Space Research:*** *Small scale astronomy and exploration missions*
5. ***Climate Monitoring:*** *Network of satellites to monitor climate change*
6. ***Earth Observation:*** *Provide real-time imaging capability with satellite swarms*
7. ***Agriculture Monitoring:*** *Improve crop production using remote sensing data*
8. ***Microgravity Research:*** *Use the space environment to gain new insights*
9. ***Pipeline Monitoring:*** *Monitor critical infrastructure using satellites*

10. ***Signal Intelligence:*** *Use small satellites to ensure the security of our nation*
11. ***Education and Training:*** *Train the next generation scientists & engineers*
12. ***Telecommunications:*** *Provide global connectivity using small satellites*
13. ***Technology Validation:*** *Test your latest technologies onboard a small satellite*

Summary

- Nanosatellites and CubeSats have matured from pure educational projects to in-orbit demonstrators
- Proof that demanding scientific and technological missions can be carried out with small satellites at low cost and within short timescales
- Industry and Space agencies are increasingly using nanosatellite technology
- Commercial services are already in place using constellations
- Reliability increased: professional implementation
- Tailored PA/QA standards introduced
- Next astronomy mission can make use of recent developments in processors and communication subsystems
- Coordinated frequency bands should be used instead of traditional amateur radio bands to avoid interference and to provide higher data throughput
- Large number of spacecraft require strict adherence to existing rules and procedures to avoid harmful interference and space-debris problems
  - Authorisation, Registration, Frequency coordination and Compliance with "Code of conduct"

Turn-key CubeSat and nanosat/picosat missions are possible with the help of Innovative Solutions from Consortium of Space Scientists, MSMEs in Space Programmes under the initiative of ITCA. ISISpace engineers were responsible for the integration of 101 CubeSats onto the PSLV launch vehicle of ISRO, a true world record has been created with a launch of 104 Satellites (3 more by ISRO)!. Among these 101 satellites, there are 3 satellites where ISISpace, Netherlands played a major role in the design, development and implementation of the spacecraft. They are able to deliver small satellites ready for launch in 6 to 18 months. They also have ample experience with working with a broad range of standardized CubeSat and nanosat parts from various vendors and if needed, customized solutions will be implemented. Customers for satellite missions include government agencies, research institutes, universities and commercial companies.
During ITC 2018, an exclusive Sensitization Seminar "Capacity Building for Student Satellite" has been planned with the help of International experts, which will cover and provide overall bird's eye view of the above major components of Satellite Programmes. ITCA also will network with Global leaders to get various opportunities for funding the entire projects on affordable terms and conditions.

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Acknowledgement: *Indian Technology Congress Association (ITCA) thank profusely all the above authors and web portals/organisations for their original contributions in the area of small satellites and have provided very useful insights for better understanding of the subject.*

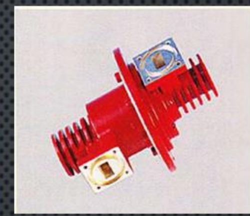
Indian Technology Breakthroughs (Space, Defence, Bio, Agri, IT, start-ups and MSME's ….)

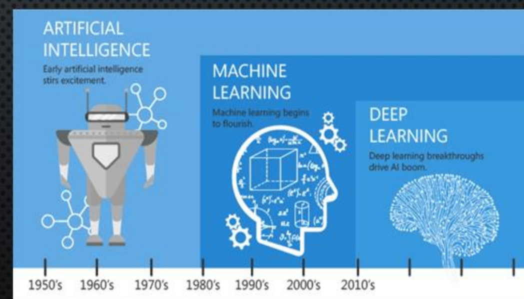
Engineering Education Outlook (Dynamics, OBE, learning crisis, research funding)

Digital Technologies (Industry 4.0, AI, social & mobile, Predictive analytics, robots, cobots, IOT, Cloud, 3D printing and VR)

Future Skills and Employment opportunities (Connected campus placements, upskilling)

Society Changing requirements (Socio- Economic, Environment and Technological)





INDIAN TECHNOLOGY CONGRESS

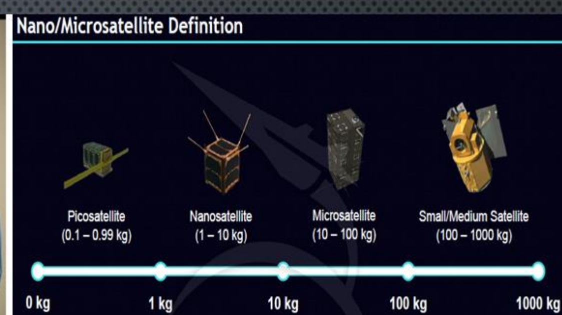
Connect :::::: Network :::::: Collaborate

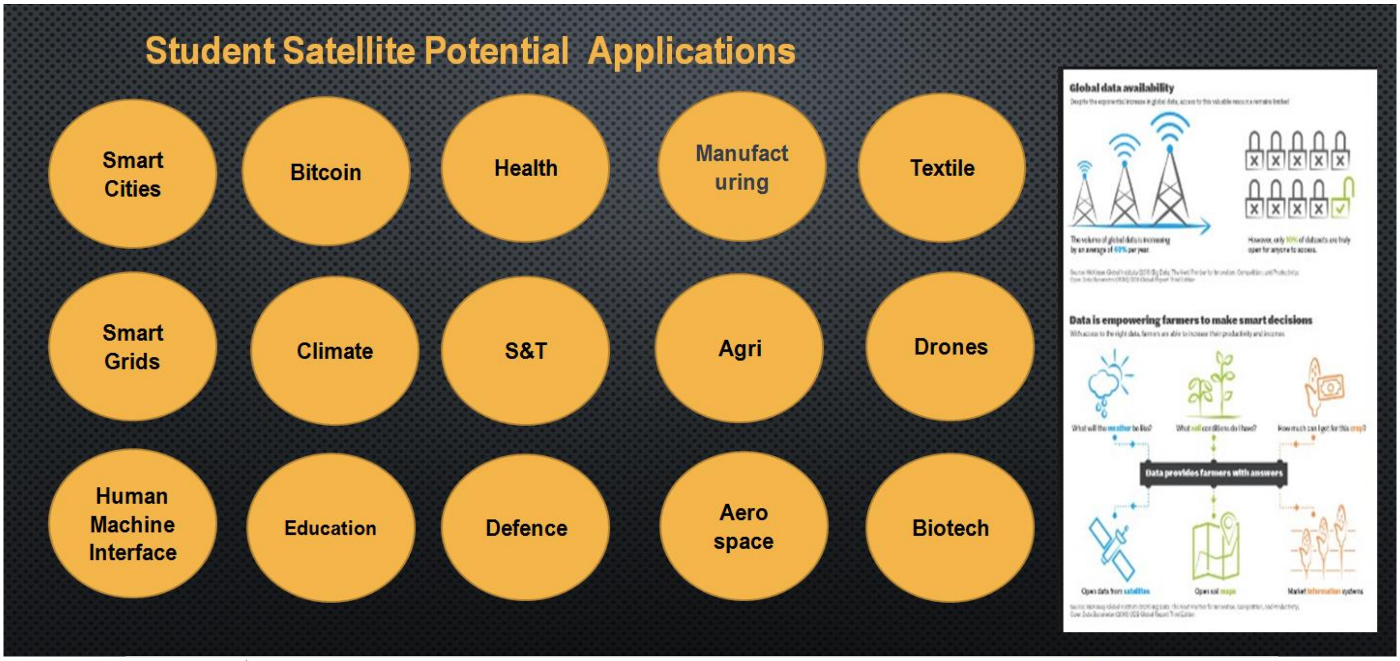
Small Satellite Revolution

- Cost, and Delivery Time
- Novel Application
- Lower orbit
- Payload Development and Integration
- Internships and Exchange Programmes
- Launch Services- Affordability
- Ground Stations
- Commissioning and Operations Support
- Training and Mentoring

Small Satellites are Disruptive Innovation
New Dimension to Global Space Market

Classification of Satellites





IIPE Chapters interested in Launching Their Own Satellites or to establish the UNISEC India Chapter at Their Institutions can contact: Dr. K. Gopalakrishnan, National Secretary, IIPE at profgoki@yahoo.com or M: 98451 73730

1ST International Seminar on Students' Satellites

NIMHANS Convention Centre, Bangalore, India, 5-6 September 2018

India- Israel Partnership

- Innovation, Robust Technology Base, Disruptive Technologies
- Academic Research to Products and Solutions
- Approach to Outreach Educational Programmes – Industry & Institute
- Mastered in Space Technology
- Strong in Communication, Observation Science and Education
- International Co-operation, Bilateral Agreements with India including Student
- Exchange Programmes and Joint Projects
- Funds - Grants, Soft Loans etc

How Institutions Can Engage

- Build Strong "Space Technology" Competencies
- Hands on Development Experience- Students and Faculty Members
- More Industry Interaction (Real Time)
- State-of-the-art Technology Interventions
- Create New Job, Start-ups and Incubation facilities
- Nurture Future Space Engineers/Scientists
- Technology Demonstration - S&T Research
- Support Education Outreach
- Make Students Future Career Ready

ITCA's Global Technology Cooperation Initiatives with ISRAEL

Indian Technology Congress Association

ITCA Delegation led by its **President, Dr. L.V. Muralikrishna Reddy** had a meeting with **Mr. Ofir Akunis, Israel's Minister of Science, Technology and Space** at the **Israeli Parliament "Knesset"** on **Wednesday, 06 June 2018.** Collaboration and joint pursuit in the areas of capacity-building for futuristic requirements; and small satellites and space applications ecosystem were discussed during the meeting.

The ITCA team comprising of **Mr. M. Milind, Dr. K. Gopalakrishnan, Dean (R&D), NHCE, Dr. Enti Ranga Reddy** and **Dr. Wooday P. Krishna** briefed the Israeli team about the forthcoming **Indian Technology Congress-2018** at **Bengaluru** during **05-06 September 2018** and invited him to the event.

2nd International Programme on Students' Satellite: Mission 2022

28-29 November 2018, FKCCI Auditorium, Bangalore

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