Commercial missions using cube/nanosats

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Introduction

- Cubesats have appeared in the beginning of the century as a tool for university students to practice with space projects without the limitations of a "real" project in terms of costs, reliability, applications, time frame etc.
- The success was above the expectations of the creators of the cubesats.
- A few companies were then created with academic origin, students and/or professors that had worked with cubesats at their universities had created their own companies.

- Other type of commercial opportunities connected to the cubesats and not only those of equipment supplier.
- Services that can be provided by cubesats and their data obtained from space.
- This type of commercial opportunities seems to be larger.
- For this to become truth, necessary more reliable, capable and application driven low cost platforms, affordable to a larger number of investors and new companies.

Remote sensing

- Best perspective up to now to commercial applications of cubesats.
- Technical points limits for combining resolution and image quality (MTF - modulation transfer function) :
  - the physics of the payload optical instrument and the diameter of the lens
  - the size and volume of the platform and the payload unit volume
  - altitude of the orbit
  - a great challenge to the academic community in order to find smaller and more capable cameras for these type of nano and cubesats.

Altitude (km), resolution (m) and optical diameter (cm) trade off - 600, 5, 5 ; 550, 1.25, 10 and 200, 0.15, 50

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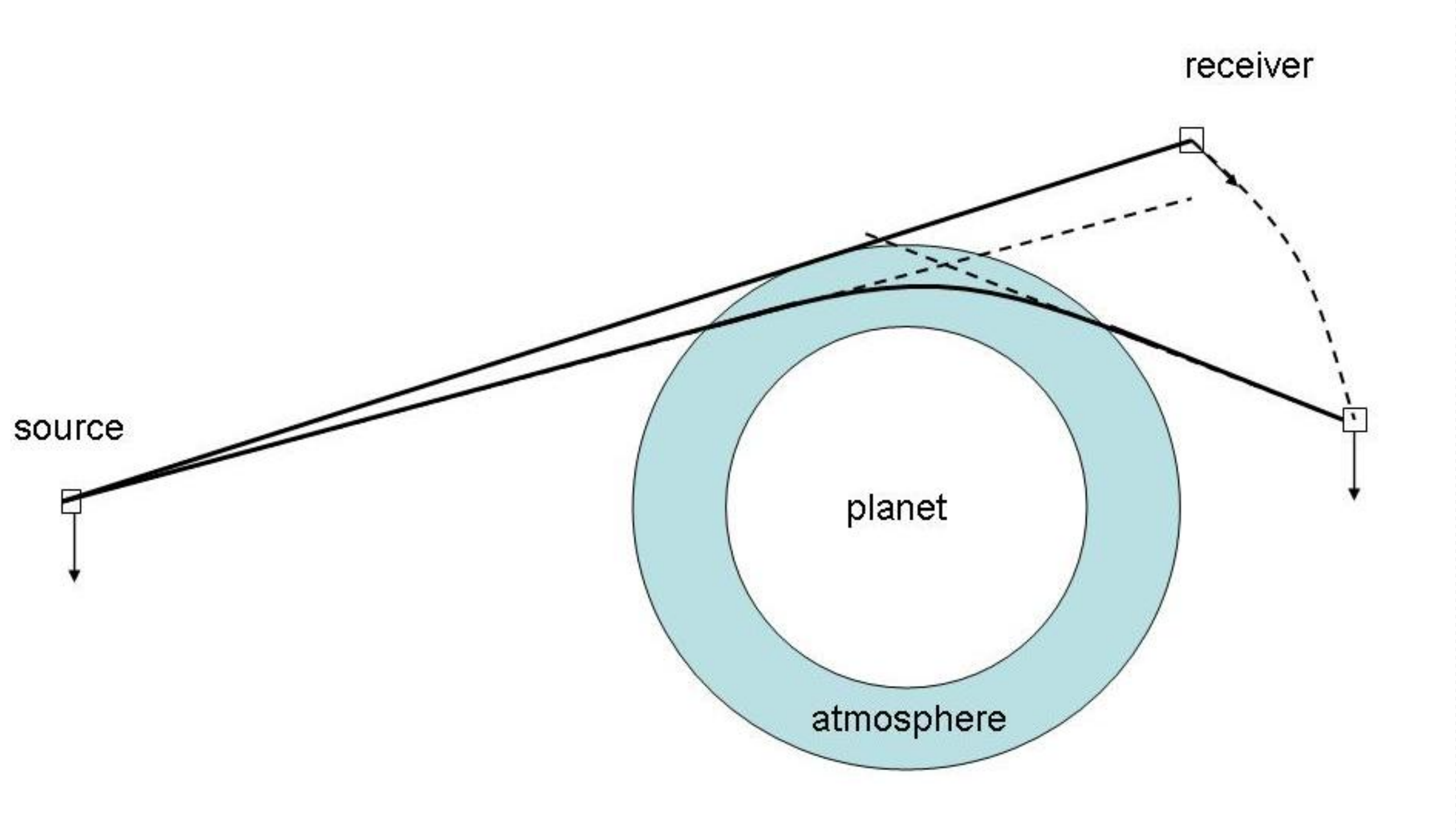
Remote sensing

- Success in achieving initial capital for new companies using cube and nanosats for remote sensing constellation missions.
- Resolution may not be the main factor to consider, although a few applications require resolution under 1m., such as for defense and urban.
- An application that does not require high space or temporal resolution for the constellation is for natural resources and agriculture.
  - Resolution from 5 to 7 m.
  - Revisit period from 7 to 15 days to determine the number of satellites
  - Competitive to access a growing market from government and other big potential customers, based on a 2014 survey of images purchased by the governmental companies (in Brazil).

Micro meteorology

- New technique (1995) for atmospheric measurements based on radio occultation
  - Constellation with GPS receivers
  - Measures the change in angle of the signal when received by two different receivers.
  - The angle correlates with parameters in the ionosphere.
  - Uses the Doppler shift of the signal given the geometry of the emitter and the receiver
  - The amount of bending can be related to the neutral atmosphere (below the ionosphere) and information on the atmosphere's temperature, pressure and water vapour content can be obtained from it.

Radio Occultation



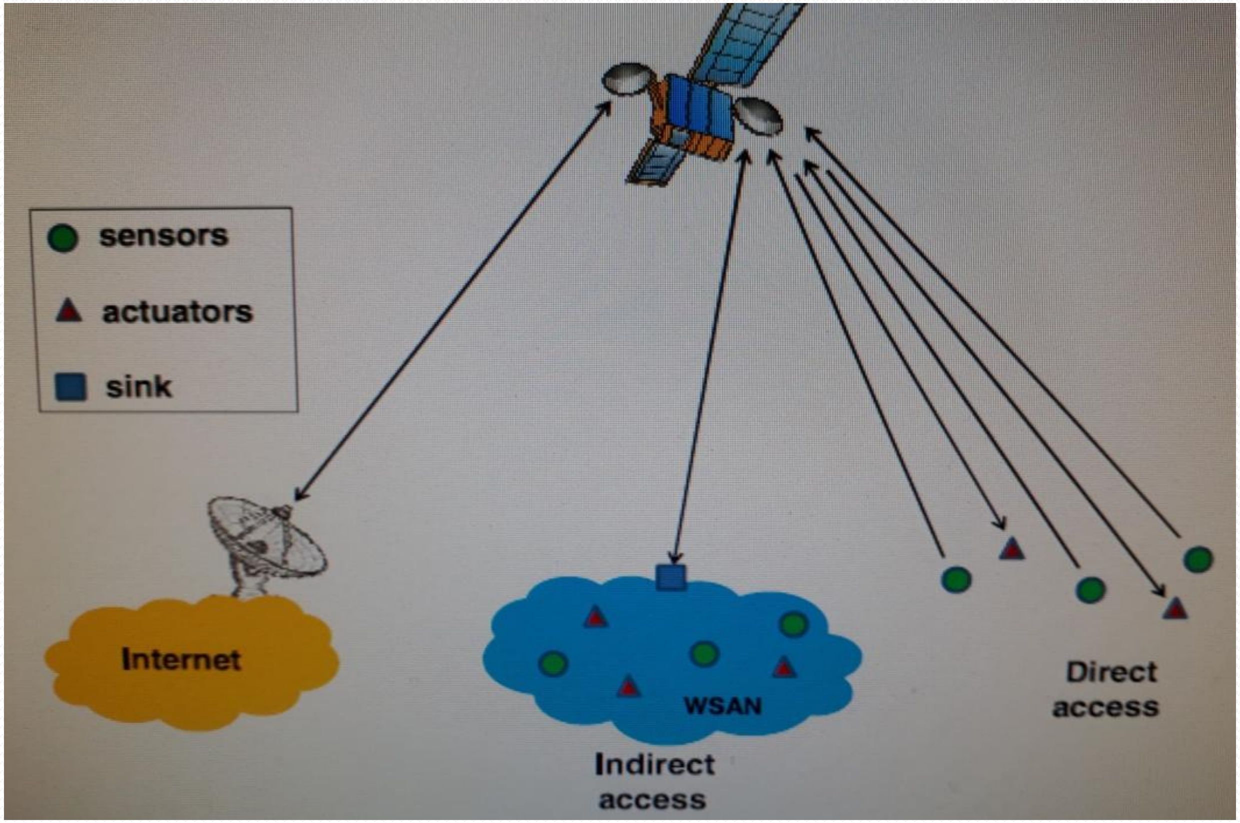
Radio occultation missions

- COSMIC currently provides this radio occultation data to generates weather data.
  - Not a private mission nor uses cubesats.
- More than one company today have either design or launched their precursosr 3U cubesats for this application.
  - Contracts already have been awarded to these companies by NOAA.

IoT

- Data collection with cubesats is not a new potential application.
- IoT may be seen as an extension of data collection missions
  - New application with great potential for commercial results for companies providing services with cubesats.
  - Companies designing their constellations and launching their precursors.
  - Principle is similar to that for data collection
    - Transmitter on the ground sends local data to the satellite which is retransmitted to a ground station.
    - The "station" can acquire different forms
    - Machine to machine (M2M) communication
    - Large agricultural areas for precision agriculture farming.

Satellite IoT



Telecommunication

- Store forward communication.
- Lesss costly system as the delivery time interval may be less important for the customer.
- Used experimentally in:
  - Defense for over the horizon store forward communication
  - Amateur radio VHF/UHF frequency.

Real time communication

- Improvement in cubesat communication technique may greatly enlarge the possibilities of communication applications.
  - Recently announced (Feb. 2017)
  - Development of a small Inmarsat terminal in L-band tested for more than one year in secrecy in space.
    - 6U cubesat weighing 13 kg.
  - The cubesat data relayed with the Inmarsat constellation of geosynchronous L-band satellites and its Broadband Global Area Network (BGAN).
  - With three Inmartsat satellites in geosynchronous orbit operators maintain continuous contact with the cubesat in low Earth orbit.

Others

- AIS and airplanes tracking.
  - Application tested with success by two 3U cubesats, one at a time, by the same company, the second one by more than one year.
- More complex scientific missions such as the ones going to Mars and Moon with cubesats.

Investment funds

- Important link between the academia and the private sector for the development of commercial missions using cube and nanosats.
  - Risk evaluation seems to be much more restricted in less technology developed regions
  - Local investors with feasible resources to such necessary venture.
  - Government participation look other strategic features such as geographic development and local content.
    - Creates bureaucracy and less weight in the pure commercial attractiveness of the application.

Standards

- Growing possibilities of using cube and nanosats (nU) for commercial application, has created the need for new standards for their future developments.
  - "Space systems — Cube satellites (CubeSats)"; DRAFT INTERNATIONAL STANDARD ISO/DIS 17770; Sept. 2016.
  - "Space systems — Design qualification and acceptance tests of small spacecraft and units"; DRAFT INTERNATIONAL STANDARD ISO/DIS 19683; Nov. 2016.
  - "CubeSat Standards Handbook A Survey of International Space Standards with Application for CubeSat Missions"; 2nd. Draft; ed. by Artur Scholz; published by The LibreCube Initiative; Oct. 2016; available at https://drive.google.com/open?id=0B_-jwG2gLchfc25UbERoeFQwcUE

Reliability

- Reliability and product assurance may be at the moment and in the near future a significant contribution the academic and R&D world can give to the cube/nanosat industry growth.
- Electronic components are becoming more and more reliable, efficient and powerful.
  - A space heritage for many of these components and subsystems are being created.
  - Even for radiation resistance, specifically for cumulative dose
    - Tests performed with non space qualified components have shown results that are close to the required radiation thresholds.
    - Cubesat platform suppliers are starting to offer radiation protected subsystems for cubesat missions
  - Fault tolerant designs and software are being used both for components, as FPGAs and subsystems.
- Increase of mass, as a way to increase the nominal life of cubesat launched from very low orbit, such as from the ISS (in the front drag area and mass relation of the cubesat), may also add opportunities for redundancies and radiation protection.

Launchers

- Small launchers able to launch cube and nanosats as its major payloads, will open new opportunities for many countries and industries to launch their constellations covering their main region of interest.
- The recent launch of 102 cubesats with a PSLV is a demonstration of this potential.

Conclusions

- Possibilities of cube and nanosats to become more and more useful into commercial space missions.
- <u>A lot of work will have to be done for that in R&D</u>
  - The role of the academic community is of great importance in areas such as optics, processes, reliability, product assurance, communication, software and others.
- A challenge to learn the type of mission can cube and nanosats be economically be used.
  - The feasibility of small companies to explore it.
- A combined R&D and entrepreneurship effort to make commercial cube and nanosat missions sustainable.

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