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# Nanosat tracking and identification techniques and technologies

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# NanoSat tracking and identification: techniques and technologies

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# Abstract

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Nanosats (and CubeSats, ‘SmallSats’, etc.) are of order 10 cm in size, and are at or near the limits of what can be tracked and characterized, using existing space surveillance assets. Additionally, given the CubeSat form-factor, they are often launched in large numbers (scores), and can be virtually identical. Thus are they difficult to track and to identify.

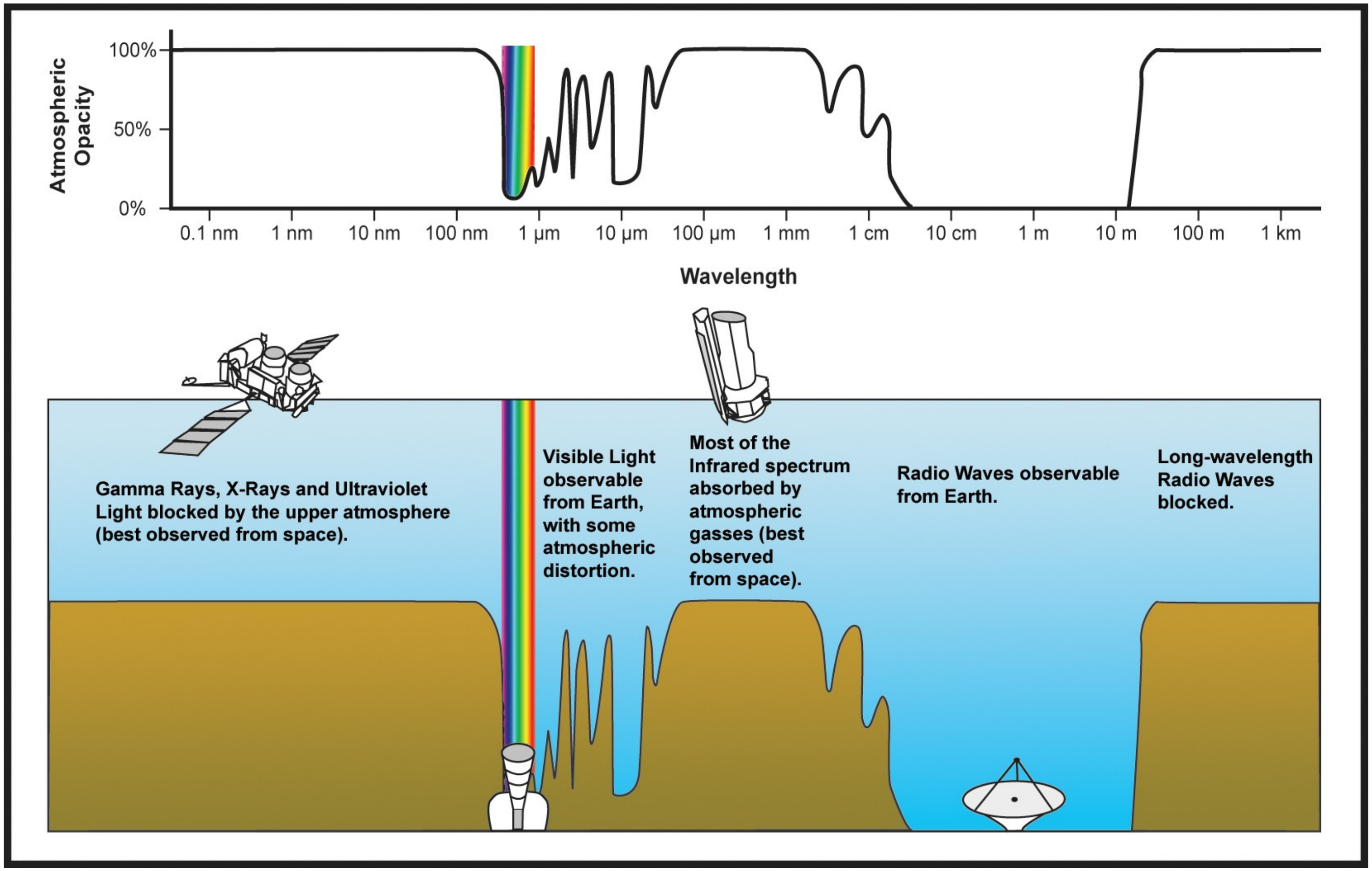
We have identified a number of technologies that future nanosat missions could employ that would enhance the trackability and/or identification of their satellites when on-orbit. Some of these technologies require active illumination of the satellite with electromagnetic energy, either in the radio frequency region, or in the optical frequency region, and some are passive in nature. We have also enumerated a number of techniques that observers might employ to facilitate tracking and/or identification of small space objects that do not carry any special tracking or identification technology.

From a space traffic management perspective, objects that can “self report” their orbital information and identity can help to relieve some of the surveillance burden from space surveillance assets.

# Overview

- Since the start of the space age, various techniques have been devised to identify and/or obtain trajectory information for satellites
  - *50s—60s era satellites would be considered “small-sats” today*
    - *Sputnik was RF beacon; USSR had no satellite surveillance capability*
  - *Some techniques return a satellite ID, some return trajectory information, some both*
  - *Active v. Passive*
    - Active: requires e/m radiation to be transmitted from ground to spacecraft
    - Passive: relies on energy transmitted (or ambient energy reflected) from the spacecraft
  - *Novel techniques*
    - “Other” methods that don’t fit into the above categories

# Physics of radiation propagation through the atmosphere limits how information can be received from satellites




Ref. 1

***Atmospheric "windows" limited to optical and radio frequencies***

# Standard Space Surveillance Network tracking techniques

| | Detect/Track | Signatures | Images |
|---|---|---|---|
| **EO Approaches:** | | | |
| Passive | | | |
| VNIR (reflected light) | Near Earth:<br>VAST (Maui)<br>Deep space (Night):<br>GEODSS<br>Raven<br>SST (in development)<br>Deep Space (Day):<br>Being considered for R&D | Deep Space (Night):<br>GEODSS photometry<br>AMOS photometry<br>Multi-spectral photometry<br>Non-image shape recovery<br>Deep Space (Day):<br>None | Near Earth:<br>Daylight speckle<br>Terminator AO<br>Deep Space (Night):<br>Night only interferometric R&D<br>Deep Space (Day):<br>None |
| Thermal IR | Near Earth:<br>AMOS LWIR acquistion/tracker | Near Earth (Day/Night):<br>AMOS LWIR tracker/radiometer | Near Earth (Day/Night):<br>AMOS LWIR camera |
| Active | | | |
| Laser illumination | Near Earth:<br>Laser guidestar AO (R&D)<br>Active track (R&D))<br>Deep Space:<br>Laser guidestar AO (R&D) | None | Near Earth:<br>Full night (R&D)<br>3D imaging (new concept)<br>Deep space:<br>LRIL ISAL (R&D) |
| **RF Approaches:** | | | |
| RADAR | | | |
| Monostatic | Near Earth:<br>Beacon and skin track radars<br>Deep Space:<br>(Limited capability) | Near Earth:<br>Narrowband radar<br>Deep Space:<br>(Limited capability) | Near Earth:<br>Wideband imaging radar:<br>Haystack<br>Kwajalein<br>Cobra Judy<br>BMD X-band Radar(s)<br>Deep Space:<br>Limited capability |
| Bistatic | Near Earth:<br>Radar Fence (in development) | None | Near Earth & Deep Space:<br>None (R&D at MIT/LL?) |

***What additional techniques/technologies could be brought to bear, especially for smaller satellites and debris?***

## *Ways to lessen impacts of NanoSats on SSA/STM operations 1/2*

- NanoSats (~10 cm or less) often at limits of detectability/trackability of Space Situational Awareness (SSA) or Space Traffic Management STM) systems
  - *Also often nearly identical ("**n**U" form-factor), and increasingly launched ~scores at a time, pehaps unpowered*
  - *Difficult for SSA/STM systems to distinguish between the objects*
  - *Lack of initial orbital information may delay owner/operator (O/O) acquisition of newly launched satellite*
- Given experimental/educational nature of many NanoSats, O/O "tenure" may be shorter than orbital lifetime of object
  - *Would like to identify techniques that work even if O/O unavailable*
- How could STM Regulators and future O/Os partner to mitigate impacts on space operations?
  - *Identify technologies for O/Os to choose from during mission design*
  - *Better communications before, during, and after active phase of mission*

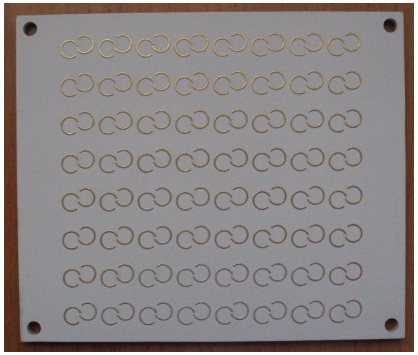
Ref. 2

# *Ways to lessen impacts of NanoSats on SSA/STM operations 2/2*

- For SSA/STM systems:
  - *"Novel" techniques for tracking and identification of small space objects*
    - Implement techniques or import results from appropriate providers
    - New classes of information regarding space objects
      - *In many instances effective on existing space objects*
  - *Ingest O/O measurements/data "machine to machine"*
    - Key for ~continuously thrusting space objects
    - Reduces burden on RF/Optical trackers, potentially better accuracy
- For Owner/Operators:
  - *Suggested technology choices to enhance RF or Optical signature of their space object*
  - *Self-reporting of object ID and/or orbital trajectory*
    - Ultimate goal would be to provide this autonomously throughout entire space object orbital lifetime

# Case 1: Active Illumination (optical laser or radar)

- RF techniques:
  - *Ka-band radar reflector panels*
  - *Unique deployable booms/masts/antennas/etc.*
- Optical techniques:
  - *Corner cube reflectors*
    - ILRS pushing towards mm-level precision, cm-level demonstrated
  - *Satellite Laser Ranging*
    - Demonstrated m-level precision



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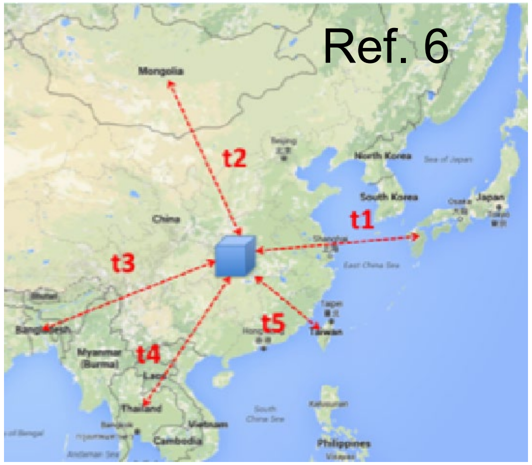
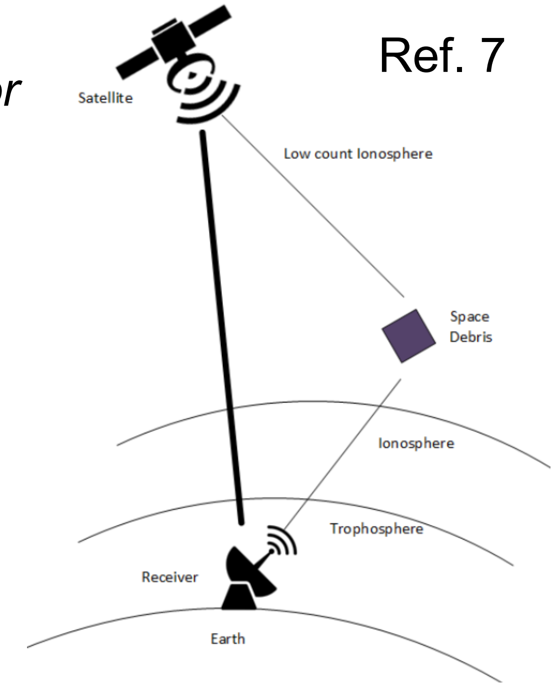
# Case 2: Reflected or emitted energy from object

- RF techniques
  - *Multi-ground site radio time-of-flight ranging*
    - Uses transmitted radio signals from space object
  - *Doppler-ranging from reflected ambient RF*
    - Radio, TV, GNS satellite signals, etc.
- Optical techniques
  - *Reflected Earth-shine (for objects in eclipse)*
  - *Long-wave IR self-emission (for objects in eclipse or during daylight)*
  - *Precision characterization: Filter photometry, spectroscopy, SWIR, UV, etc.*
    - Characterization of object to distinguish unique signature features
    - Feature-aided tracking



# Case 3: Interrogation of object for information

- RF techniques (NB: always-on RF beacons not allowed)
  - *Transmission of orbit information (e.g., from on-board GPS receiver)*
    - Via satellite native telemetry stream, specialized ground-station, or ”IOT” solution (e.g., Iridium, GlobalStar, etc. radio)
    - On-board RFID
- Optical techniques
  - *Coded optical laser pulses (e.g., LANL ELROI)*
  - *Single or multi-color LED signals (e.g., Morse code)*

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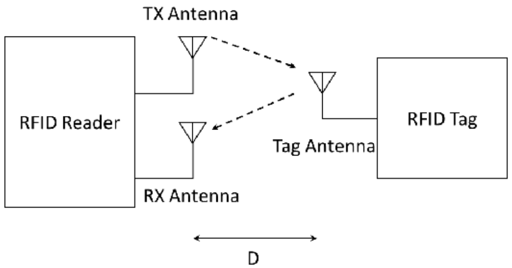


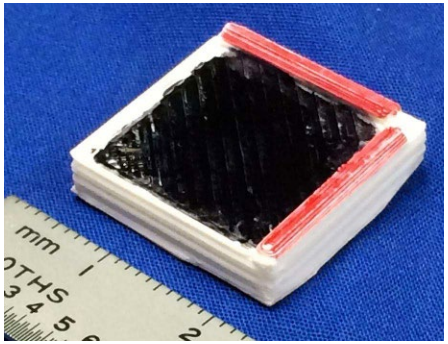

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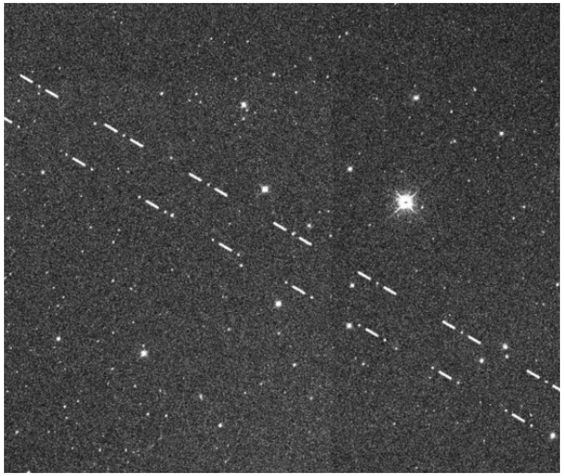

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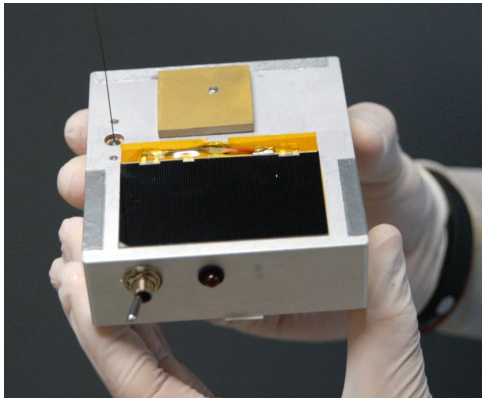

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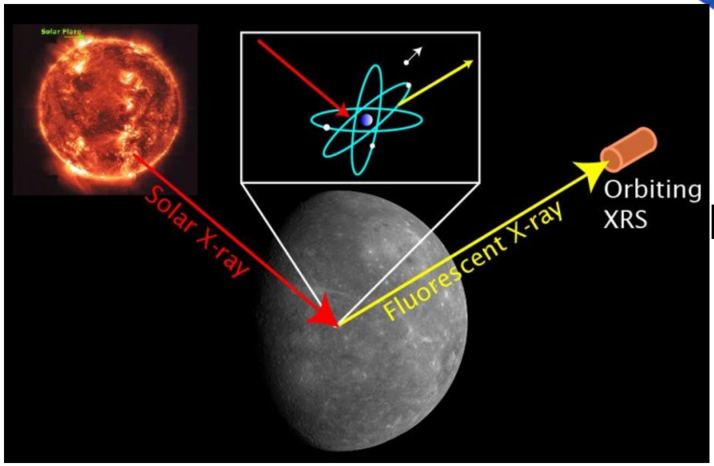
# Case 4: "Other" techniques

- Soft X-ray spectroscopy
  - *Utilizes high energy solar particles/photons to generate characteristic x-rays from spacecraft materials*
  - *Needs space-based X-ray telescope*
- Inflatable/deployable mylar balloon/sail/mast
  - *Enhances both RF and Optical cross-section*
  - *Shortens time to de-orbit the object*
- Resolved optical imagery
  - *Commercial services from on-orbit cameras*
    - Must be "close"; regulatory conditions on non-consenting objects

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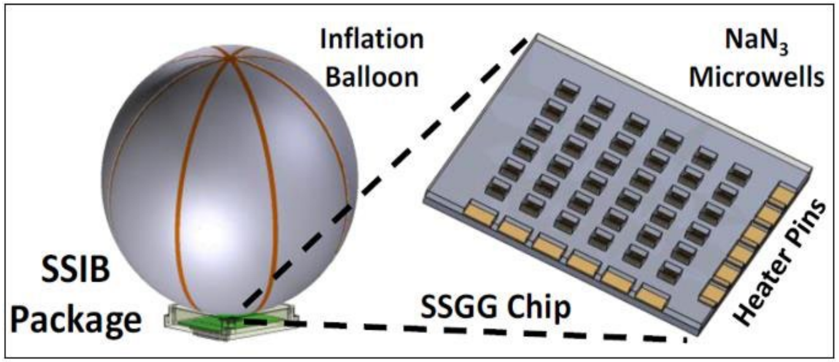


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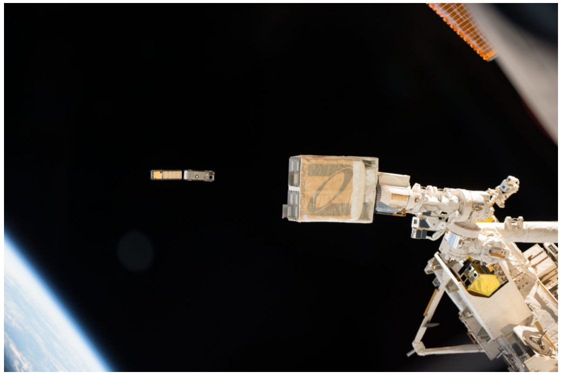

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# Conclusion, and look-ahead

- There exist a variety techniques and technologies that can enhance the identification and/or tracking of space objects
  - *Some techniques amenable to objects already in orbit*
  - *Many technologies exist as choices for owner/operators to ”design in” for upcoming missions*
- These data would need to be transmitted to, and incorporated by, STM Centers.
  - *Open, two-way channels of communications between Regulators/STM Centers/Satellite O/O.*
  - *Development of standard formats and tools to allow easy transmission, vetting, ingestion, and processing of these data*
- Economic incentives from STM Centers would enhance quality and quantity of new data (*i.e*., “make a market”)

***Many of these open-source technologies and techniques are available for use now or in near future…***

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