A Concept of Nanosatellite Small Fleet for Earth Observation

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Multisatellite missions survey

Extensive research of Distributed Satellite Systems (DSS) missions utilizing small satellites, have been performed. The survey consisted of 79 missions (41 past and current) and identified:

- Only 3 Fractionated spacecraft missions (all future or planned)
- Only 6 missions involving the concept of Federated Spacecraft System

**Small platforms used in multisatellite missions**
- Nano: 78%
- Micro: 9%
- Pico: 4%
- Femto: 1%
- Multiple: 8%

**Status of small platform multisatellite missions**
- Future: 38%
- Current: 24%
- Past: 38%
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Multisatellite missions survey

- Almost half number of nanosatellites up to now were part of multisatellite missions.
- Small number of formation flying missions related to Earth Observation.
- No formation flying missions related to satellite imagery were identified.
Earth Observation systems

- Frequent (e.g. daily) data updates (low revisit time) requires the use of multiple satellites (constellation).
- High measurement resolution $\rightarrow$ narrow field of view
- Narrow field of view $\rightarrow$ more satellites to achieve daily coverage
- Some of the gathered data may be useless due to:
  - The mapped area is not important for the user
  - The mapped area have not changed since last visit
  - The mapped area is covered by clouds
Earth Observation systems

☐ Data may be enhanced by proper selection of target point.

☐ Selection of target point → decision making process (algorithm).

☐ Decision making algorithm requires input data
  ☐ acquired during previous measurements
  ☐ provided by external source
Earth Observation systems

- Decision making algorithm:
  
  To decide whether an area should be targeted is to find if it has changed since last visit.

- Requirements:
  - Previously gathered data for comparison.
  - Real time data for comparison.
  - Method of how to decide that a change occurred.

- It seems easy for a human to decide whether an essential change have occurred – it is not so for a computer.
Earth Observation systems

- The detection of change can be accomplished using coarse data only.

- Coarse measurement used to determine the change only – *There is something there.*

- Fine measurement provides actual data – *It is a tank.*
Conventional EO system

- Two uncoupled satellites on Low Earth Orbit.
- Both satellites pass over the same area within several hours/days.
- First satellite performs coarse measurement (ex. low resolution photo).
- The acquired data is sent to the ground and analyzed.
- The target for fine measurement is selected and the commands are sent to the second satellite.
- The second satellite flies over the same area and acquires narrow field of view, fine measurement (ex. high resolution photo).
- The acquired data is sent to the ground station.
Conventional EO system

Data acquisition timeline:

- Corse measurement acquisition by 1<sup>st</sup> satellite
- 1<sup>st</sup> satellite awaiting for ground station contact
- Ground station contact with 1<sup>st</sup> satellite
- Coarse measurement downlink
- Corse data analysis, decision making algorithm
- Target for fine measurement selected
- Awaiting for contact with 2<sup>nd</sup> satellite
- Command uplink to 2<sup>nd</sup> satellite
- 2<sup>nd</sup> satellite awaiting for target location flyover
- Fine measurement acquisition by 2<sup>nd</sup> satellite
- 2<sup>nd</sup> satellite awaiting for ground station contact
- Ground station contact with 2<sup>nd</sup> satellite
- Fine measurement downlink
Conventional EO system

Delay between measurements – data relevance:

- change caused by moving object

- Reference measurement

- Coarse measurement
  - Change detected – area for fine measurement selected

- Too long delay between coarse and fine measurement results in useless data
Formation Flying Earth Observation System

- Two satellites in a trailing formation on Low Earth Orbit.
- Both satellites pass over the same area within several seconds/minutes.
- First satellite performs cores measurement (ex. low resolution photo).
- The acquired data is analyzed (on orbit) and the target for fine measurement is selected.
- The second satellite flies over the same area and acquires narrow field of view, fine measurement (ex. high resolution photo).
- The acquired data is sent to the ground station.
- Both satellites communicate through Inter Satellite Link.
Formation Flying Earth Observation System

Data acquisition timeline:

- Corse measurement acquisition by 1st satellite
- Corse data analysis, decision making algorithm
- Target for fine measurement chosen
- Command uplink to 2nd satellite via Inter Satellite Link
- 2nd satellite awaiting for target location flyover
- Fine measurement acquisition by 2nd satellite
- 2nd satellite awaiting for ground station contact
- Ground station contact with 2nd satellite
- Fine measurement downlink
Advantages:

- Shorter acquisition time

- No delay between the acquisition of coarse and fine data – the acquired data will always be relevant.
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WUT Satellite Simulation Model

- Evaluating the performance of satellite subsystems required for precise formation flying.
- Formulation of requirements for:
  - Attitude and Orbit Control System
  - Inter satellite communication system
Simulation model requirements:

- Model applicable to formation flying LEO satellite mission.
- LEO environment model with relevant orbital perturbations, lighting conditions etc.
- Satellite actuators, sensors and other subsystems models (such as payload, power or communication).

Environment modelling:
- Gravity
  - Non-spherical Earth's gravity
  - Third bodies gravity (Moon, Sun)
- Aerodynamics
  - Satellite aerodynamic properties (free molecular flow)
  - Air density
  - Atmosphere wind
- Solar radiation Pressure
  - Satellite reflective properties
  - Earth's shadow
  - Earth's magnetic field
WUT Satellite Simulation Model

Actuators modelling:
- Thrusters
  - Mainly cold-gas for nanosatellites
  - Influence on satellite's inertia
- Magnetotorquers
- Momentum exchange devices
  - Mainly reaction wheels for nanosatellites

Sensors modelling:
- Accelerometers
- Gyroscopes
- Magnetometers
- Sun and Earth sensors
- Star trackers
- GNSS receivers
  - Allows to determine both position and attitude for Low Earth Orbit satellites
- Other sensors
  - Payload related sensors
  - Cameras for navigation

Satellite modelling in terms of system performance:
- Electrical power sources:
  - e.g. solar arrays, batteries
- Electrical power dumps:
  - e.g. actuators, sensors, payloads, communication
- Data sources:
  - e.g. payloads, sensors, communication system
- Data dumps:
  - e.g. communication system
- Communication with ground station

![Satellite Simulation Model Diagram]

- Data usage
- Data generation
- Electrical power generation
- Electrical power consumption
- Input parameters
- Output parameters
Conclusion

- A concept of formation flying satellites for Earth Observation is proposed.

- Proposed system decreases time of data acquisition and increases the data value.

- The performance of the proposed concept will be analyzed using WUT satellite simulation model.
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Thank you for your attention