Development of the Picosatellite Dispersion Estimation and Optimization Tool with Applications on DUST

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Agenda

- DUST Intro
- PDOT Intro
- DUST Case Study
- Other Applications
What is DUST?

- Distributed Universal Satellite Technology (DUST)
- Student Designed
- Fractionated CubeSat technology
  - Rapid deployment of large numbers of satellites
  - Record and transmit position/sensor data
  - Exploit economies of scale
What is DUST? (cont’d…)

- CubeSat compatible framework:
  - Allows inter-CubeSat communication
    - Swarms of >1U spacecraft
    - Fractionated CubeSat systems
  - Deployed from standard CubeSat Launcher

- Cutting edge design
  - Modular, enabling a multitude of payloads
    - Power, Communications, C&DH, & Payload Interface on one board
Design Details

- Inter-satellite communication
  - Established using ‘mesh network’ (IEEE802.11s)
    - Cross-link capability
    - Optimized communications paths
    - Evolving links
  - Allows economies of scale
  - Downlink node (ComSat) and Router nodes (DUSTSat)

- MainBoard
  - Provides standard interface
    - Predefined subsystems
    - ‘Plug and Play’ payload
  - Supports DUST missions to be:
    - Easy to build
    - Quick to develop
    - Low cost
Mission Plan and Con Ops

- Primary Payload Orbit
- DUST Operational Orbit
- Launch
- Primary Launch Payload Deployment
- Commissioning Phase
- Mesh Network Established
- Primary Mission Phase
- Deorbit
- UM UHF
P-POD Release

Deployment Spring

ComSat

Poly-Picosatellite Orbital Deployer (P-POD)

Separation Springs

DUSTSats
DUST Constraints

- DUST architecture places constraints on constellation optimization problem
  - Mass and volume
    - P-POD specifications
  - Physical separation beyond inter-satellite communication range
    - Satellites will drift apart after deployment due to perturbation forces
    - Range from radio spec’s/tests

- Primary cause for end of mission is physical distance between satellites
What is PDOT?

- Picosatellite Dispersion estimation and Optimization Tool
- Enables the design of constellations to maximize mission lifetime subject to mass, volume, and payload constraints
- Analyzes the constellation design space
- Consists of MATLAB code interfaced with the Systems Tool Kit (STK)
What is PDOT? (cont’d…)

- Factors that influence separation are:
  - Ballistic coefficient (mass and frontal area)
  - Initial orbit
  - Satellite attitude
  - Separation spring characteristics

- Decision variable of PDOT are:
  - Satellite mass
  - Satellite frontal area range
  - Spring characteristics

- Orbit is determined by payload requirements
PDOT Design

- PDOT consists of two segments: the optimizer and the simulator
- Pass information back and forth until optimal solution is found
DUST Case Study

- Constellation size
  - 1 ComSat: 1.33kg, 0.01 m² (1U CubeSat)
  - 6 DUSTSats: 0.25kg-0.445kg, 0.003 m² - 0.01 m²

- Orbital parameters
  - Altitude: 700km
  - Inclination: 72°
  - Eccentricity: 0 (circular orbit)

- Deployment characteristics
  - Nominal deployment velocity: 1.6 m/s
  - Separation spring work: 0.005 J
Ballistic coefficient measures the ability of an object to pass through a fluid. 

\[ BC \propto \frac{\text{Mass}}{\text{Area}} \]
PDOT Results (cont’d…)
PDOT Results (cont’d…)

- Maximum mission lifetime occurs when ballistic coefficients of the ComSat and DUSTSats are similar
  - Atmospheric drag is major factor in separation
  - This is feasible for one region of the design space
- DUSTSats travel in clusters
  - Separation grows quickest between DUSTSat packs and ComSat
  - Rearrangement of satellites in the P-POD may lead to a longer mission lifetime
Other Applications

- NanoSat Constellations are gaining traction
  - e.g. ARMADA, etc.
  - Understanding constellation drift will be useful during mission planning stages
- Interplanetary small sats are also gaining traction
  - Interplanetary constellations are being proposed
    - DUST could provide a framework that enables multi-point measurement
      - PDOT used in constellation optimization
Questions?

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