Relative Navigation Schemes for Formation Flying of Satellites

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Relative Navigation Schemes for Formation Flying of Spacecraft

• Relative Navigation
• VTXO Mission
• Technologies and their suitability for deep space missions
• Summary
Relative Navigation

Earth Centered Inertial Frame (ECI)

Leader
Spacecraft

Proba 3

TanDEM-X

Occulter
Imager
VTXO Mission

- **Virtual Telescope for X-ray Observations**
- **X-Ray telescope**
  - Sub-arcsecond to milli-arcsecond resolution
  - Focal lengths hundreds of meters
  - Imager and optics Satellites
- Investigate technologies that can be adapted to a full scale virtual telescope mission for deep space or sun-earth libration points.
- Formation flying for deep-space missions enabled by diffractive Fresnel lens

VTXO with imager and optics satellite separated by hundreds of km.
RF Communications

- One configuration creates a pseudo GPS Network, however instrumentation on multiple spacecraft required

Targets mounted on deployable booms
Pseudolites flying in formation
On board targets
GPS

- Earth pointing network
- Not suitable for precision formation flying in deep space
Vision Navigation & Laser Metrology

Orbital Express ASTRO and NextSat (2007)

NASA VADRE Rendezvous Experiment (2011)
Star Trackers

• Flight proven technology, Chandra X-Ray Observatory (1999), LRO (2009), SDO (2010)

• Effective for relative positioning and attitude determination

• Cannot provide absolute positioning information

Ball Aerospace High Accuracy Star Tracker

Hydra Star Tracker
Sun and Earth Sensors

• Measure direction of Sun or Earth and provide attitude information
• Limited accuracy, require secondary system for relative positioning
• Unreliable for deep space application

Servo Corporation of America MiDES Earth Horizon Sensor

NSS Fine Sun Sensor
X-ray Pulsar Navigation
## Technical Summary

<table>
<thead>
<tr>
<th>System</th>
<th>Standalone (rel and abs)</th>
<th>Absolute Range</th>
<th>Notable Missions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio Frequency</td>
<td>N</td>
<td>Any</td>
<td>TanDEM-X</td>
</tr>
<tr>
<td>GPS</td>
<td>Y</td>
<td>Within GNSS Network</td>
<td>TanDEM-X, ETS-VII, EO-1, GRACE</td>
</tr>
<tr>
<td>Vision Based Navigation &amp; Laser Metrology</td>
<td>N</td>
<td>Any</td>
<td>VADRE, LISA, OE-1</td>
</tr>
<tr>
<td>Star Tracker</td>
<td>N</td>
<td>Any</td>
<td>CHANDRA, LRO, SDO,</td>
</tr>
<tr>
<td>X-Ray Pulsar</td>
<td>Y</td>
<td>Deep Space</td>
<td>NICER</td>
</tr>
</tbody>
</table>
Summary of VTXO Mission

• Seek to identify potential relative navigation schemes for deep space missions utilizing small satellites in place of CubeSats.
• Leverage current technologies for the VTXO 6U CubeSat Formation Flying mission
• Phased Fresnel lens with resolution significantly better angular resolution than state of the art (Chandra)
• Focal lengths on the order of 500 m. for a 3 cm. lens
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References


Support Slides
Notable Relative Navigation Missions

- DARWIN (2007)
- LISA (2030)
- XEUS (Under Assessment)
- SARah 2,3 (2019)
- TerraSar
- CartWheel
- GRACE

- Gemini
- Inspector
- SMART 2
- Starlight (ST-3)
- SSPS
- SPANP1 Tshinghua
- Terrestrial Planet Finder

- PRISMA
- PROBA-3
- SIMBOL-X
- DUAL
- EDSN
Figure 4. VTDM Concept of Operations