An Optical Survey for Space Debris on Highly Eccentric MEO Orbits

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Outline

1. Introduction
2. Current TLE Population
3. Survey Strategies
4. Observations and Results
5. Conclusion
Main Objectives

- **Background:**
  Fragmentation events (including deliberate events) in highly-eccentric MEO, in particular in Molniya-type orbits, are known.

- **Objectives:**
  - Develop observation strategies and make a comparative analyses
  - Demonstrate the feasibility and performance of the proposed observation strategies through an experimental observation campaign
  - Build-up and maintain a temporal catalogue
TLE Molniya Population

- Selection criteria
  - $60^\circ < i < 67^\circ$
  - $0.5 < e < 0.8$
  - $20000\text{km} < a < 30000\text{km}$

<table>
<thead>
<tr>
<th>Objects</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOLNIYA satellites</td>
<td>41</td>
</tr>
<tr>
<td>MERIDIAN satellites</td>
<td>4</td>
</tr>
<tr>
<td>Rocket bodies</td>
<td>73</td>
</tr>
<tr>
<td>Others</td>
<td>53</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>171</strong></td>
</tr>
</tbody>
</table>

USSTRATCOM catalogue to January 2012
Current Population

- Node distributed over the whole range
- More objects between $80^\circ$ and $160^\circ$

- 2 groups
  - $e < 0.65$
    - Similar launch dates
    - perigee < 180 deg
Current Population

- $i > 65 \Rightarrow e < 0.65$
- Most objects distributed around 63.4 deg

- Cover whole range
- Perigee for most of the objects around 270 deg
Evolution over 10 Years

- Evolution over 20 years
- Green: $e < 0.65$
- Similar distribution of orbital elements
- Node drift $-0.1°$ to $-0.2°$ per day $\rightarrow 36°/year$
MEO Observation Strategies

- Angular velocities (topocentric, OGS)
  - $V_{\text{min}} = 5\text{–}10\text{ arcs/s} \rightarrow \text{apogee}$
MEO Observation Strategies

- Phase angles (topocentric, OGS)
MEO Observation Strategies

- Where to look?
  - Geocentric passes; OGS, one night
Observations

- First observations in December 2012 at OGS, 1-m Zeiss telescope, 0.7x0.7 square degrees
- Survey fields in anti-sun direction (right ascension)
- First test field
  - all known TLE objects were found
  - no uncorrelated objects found
- Survey and follow-up observations were performed
  - In January 3 successful nights of observations
  - In February 3 successful nights of observations
  - In April 3 successful nights of observations
  - In July 3 successful nights of observations
  - In August 1 night
- Follow-up observations performed with ZIMLAT
Survey strategy with 3 fields per month displaced by 10° in right ascension
Survey Fields

- 13 nights → 13 fields
- $\Delta$RA = 10deg
- Each survey = 11 min
- 11–42 surveys/night
- 257 surveys (~47.1h)
- 30 uncorr. objects found (~0.6 objects/hour)
- Follow-up observations of 25 objects performed
- 5 objects still „active“
Uncorrelated Molniya

Molniya objects (Jan 2013 – Aug 2013)

Frequency

Orbit Arc Length [days]

E13009A
A/M ~ 0.3 m²/kg

E13039A
A/M ~ 0.001 m²/kg
Uncorrelated Molniya

Molniya objects (Jan 2013 – Aug 2013)

![Bar chart showing frequency of Molniya objects by magnitude from 14 to 20.](chart.png)
Uncorrelated Molniya

Molniya objects (Jan 2013 – Aug 2013)

Area to Mass Ratio [m²/kg]

Frequency

E13010A
A/M ~ 3.6 m²/kg
Arc ~ 60 days
Uncorrelated Molniya

Eccentricity vs Mean Motion (Jan 2002 - Mar 2013; elliptical orbits)

- UCT: 1241
- CT: 184
$e$ vs $i$

Molniya objects (Jan 2013 – Aug 2013)

+ TLE
+ Discovered
Perigee vs Node

Molniya objects (Jan 2013 – Aug 2013)
Brightness Variation

Light Curve 13039A

Magnitude

Seconds past 20130413 20:45:33
Brightness variation

![Brightness variation graph](image)
Conclusions

- Efficient observation scenarios for eccentric MEO orbits (particularly Molniya) were developed and their performance assessed.
- Test observations (13 nights) 30 uncorrelated objects found (~0.6 objects/hour)
- Objects highly variable in brightness → light curves acquired
- High percentage of higher A/M objects, also HAMR objects
- Objects often too faint to follow up with ZIMLAT, only 5 objects still in catalogue
- Observation campaign is ongoing...
Future work

- Statistical evaluation to follow (feedback to models)
- Comparison with models by using ESA PROOF-2009 program
- ESA MASTER statistical population comparison with real observations
- The “shows” and “no-shows” analysis with TLE population