Conjunction Assessment and Mitigation for GSOC Satellites

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Collision Avoidance Operation at GSOC

- Operational since 2009
  - 24/7 support by Flight Dynamics personnel
  - CDM provided by JSpOC

- Functionality
  - Conjunction detection
  - Conjunction risk assessment
  - Conjunction mitigation

- Supported satellites
  - 6 in LEO (400-510 km), 2 in GEO, and external satellites
  - Extended thresholds applied to TerraSAR-X / TanDEM-X (510 km)
Operational Satellite

- TerraSAR-X (2007-) / TanDEM-X (2010-)
  - Controlled against a reference orbit inside a tube of 250 m radius
  - Flying in a close formation with the relative distance < 500 m
  - 510 km altitude

Conjunction on 2014/03/03
Process Overview

1. Search for Potential Collision Risk
   - CDM reception
   - CDM download
   - Prediction update
   - Product distribution
   - Collision risk analysis
   - Risk detected
     - N: Inform satellite project
     - Y: Radar tracking necessary
   - Y: Radar tracking

2. Orbit Refinement
   - Radar tracking
   - Orbit determination
   - Risk detected
     - N: End
     - Y: Avoidance maneuver planning
   - Y: Maneuver implementation

3. Avoidance Maneuver Decision and Planning
   - Collision risk analysis
   - Risk detected
     - N: End
     - Y: Avoidance maneuver planning

Automatic CDM Process
Collision Risk Assessment

Conjunction geometry plot

Prediction history plot

Close Approach Geometry (T-N Plane)

Rel. Position/Cov. Ellipsoid in B-Plane
Maneuver Planning (1/2)

COSMOS 405 encounter to TerraSAR-X

COSMOS 405 encounter to TanDEM-X
Maneuver Planning (2/2)

- Maneuver effect w.r.t. maneuver epoch
- Probability
- Miss distance
- RTN components
- TCA
# Processed Conjunctions

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Altitude</th>
<th>CSM</th>
<th>CAM</th>
<th>CSM</th>
<th>CAM</th>
<th>CSM/CDM</th>
<th>CAM</th>
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<tbody>
<tr>
<td>TSX/TDX (excl.tdtx)</td>
<td>510</td>
<td>16</td>
<td>2</td>
<td>2222</td>
<td>0</td>
<td>7366 (1560)</td>
<td>4</td>
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<tr>
<td>GRACE-1</td>
<td>460 (-400)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>GRACE-2</td>
<td>460 (-400)</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>BIRD</td>
<td>510 (-480)</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>TET</td>
<td>500 (-460)</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SBW-1 (excl.ctrl)</td>
<td>GEO</td>
<td>35 (6)</td>
<td>1</td>
<td>19 (6)</td>
<td>0</td>
<td>110 (8)</td>
<td>0</td>
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<tr>
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<td>GEO</td>
<td>59 (0)</td>
<td>0</td>
<td>135 (2)</td>
<td>0</td>
<td>224 (6)</td>
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</table>

- CSM generation thresholds for TSX/TDX were enlarged in 2013 Aug.
- Message format was changed to CDM in 2014 May.
LEO Conjunction (1/2)

- Objects with high eccentricity (e.g. R/B)
  - Large object size
  - Large orbit uncertainty
    (~500 m in radial $1\sigma$)

- Multiple encounters of an object
  - Objects with similar SMA and smaller orbital plane angle
  - Critical event could change due to along-track errors
  - Higher possibility of recurrence
LEO Conjunction (2/2)

- The residual risk for critical conjunctions is still high to perform effective avoidance maneuver
- Larger orbit uncertainties are expected at lower altitude
GEO Conjunction

Alerts for GEO Satellites (2011-2013)

- Total / radial dist. < 50.0 km
- Satellites in neighboring boxes not counted
BACARDI:
Backbone Catalogue of Relational Debris Information

- **Objective**
  - Databank with preferably high completeness and high accuracy
  - Primary source: sensor data and operator data
  - Secondary source: externally generated ephemerides

- **Science and Research**
  - Databank generated from sensor network
    (tracking radar, surveillance radar, telescopes, laser tracking)
  - Fast compulation: orbit determination, propagation, object identification and detection of maneuvers and fragmentations
  - Basic algorithms implemented

- **Mission Support**
  - Orbit information, collision prediction, re-entry prediction
Collision Avoidance Operation using BACARDI

- Collision avoidance system integration with BACARDI
  - CDM process
  - Tracking radar (TIRA system, FHR) data process for conjunction assessment
  - First catalog from SMARTnet telescope available for conjunction screening end of 2015
Summary

Collision avoidance operation at GSOC
- Operational satellites in LEO (400-510 km) and GEO since 2009
- Collision avoidance of the satellites in close formation performed successfully
- The process and products for risk assessment and maneuver planning presented
- Interface with BACARDI planned

Feedback and lessons
- Results of processed CDMs and avoided conjunctions presented
- Orbit accuracy for high-eccentric orbit shall be improved
- Multiple encounters of an object shall be intensively observed
- The residual risk for critical conjunctions is still high for most orbit uncertainties
- GEO conjunction results in relation to orbit type and population presented