ESA's Process for the Identification and Assessment of High-risk Conjunction Events

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Outline

- Introduction
- Scheduled daily analyses and high-risk events
- Automated orbit determination from radar tracks
- Recent high-risk conjunction events
- Conclusion and outlook

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- Introduction
  - Conjunction analysis at ESA's Space Debris Office
  - Tools : CRASS and ODIN
  - Conjunction event statistics

Conjunction analyses at ESA's Space Debris Office

- ESA is providing an operational collision avoidance service (at present : ERS-2 and Envisat, (790 x 790km x 98.5 deg))
- Predictions from TLE data from US Space Surveillance Network
- High-risk event ($P > 10^{-4}$)
  - → Operator decision on acquisition of additional tracking data (German radar TIRA at FGAN)
    - → Improved state and covariance information
    - → Re-analysis of collision risk
  - → Avoidance manoeuvre if persisting collision risk
  - → Post-event analysis

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Tools: CRASS and ODIN

- Space debris software at ESOC - Sophisticated stand-alone tools
  - CRASS (Collision Risk Assessment Software)
  - ODIN (Orbit Determination with Improved Normal Equations)
    - Processing of tracking data
    - Generation of pseudo-tracking data from TLEs (→ initial cov.)
    - Orbit determination → states and error co-variances at conjunction epoch
  - Developed by GMV (Alarcon et al. (2004, 2005) ; Klinkrad et al. 2005)
- Software is used in operational context
  - Customisation and optimisation to ESOC mission procedures, data interfaces, computing infrastructure

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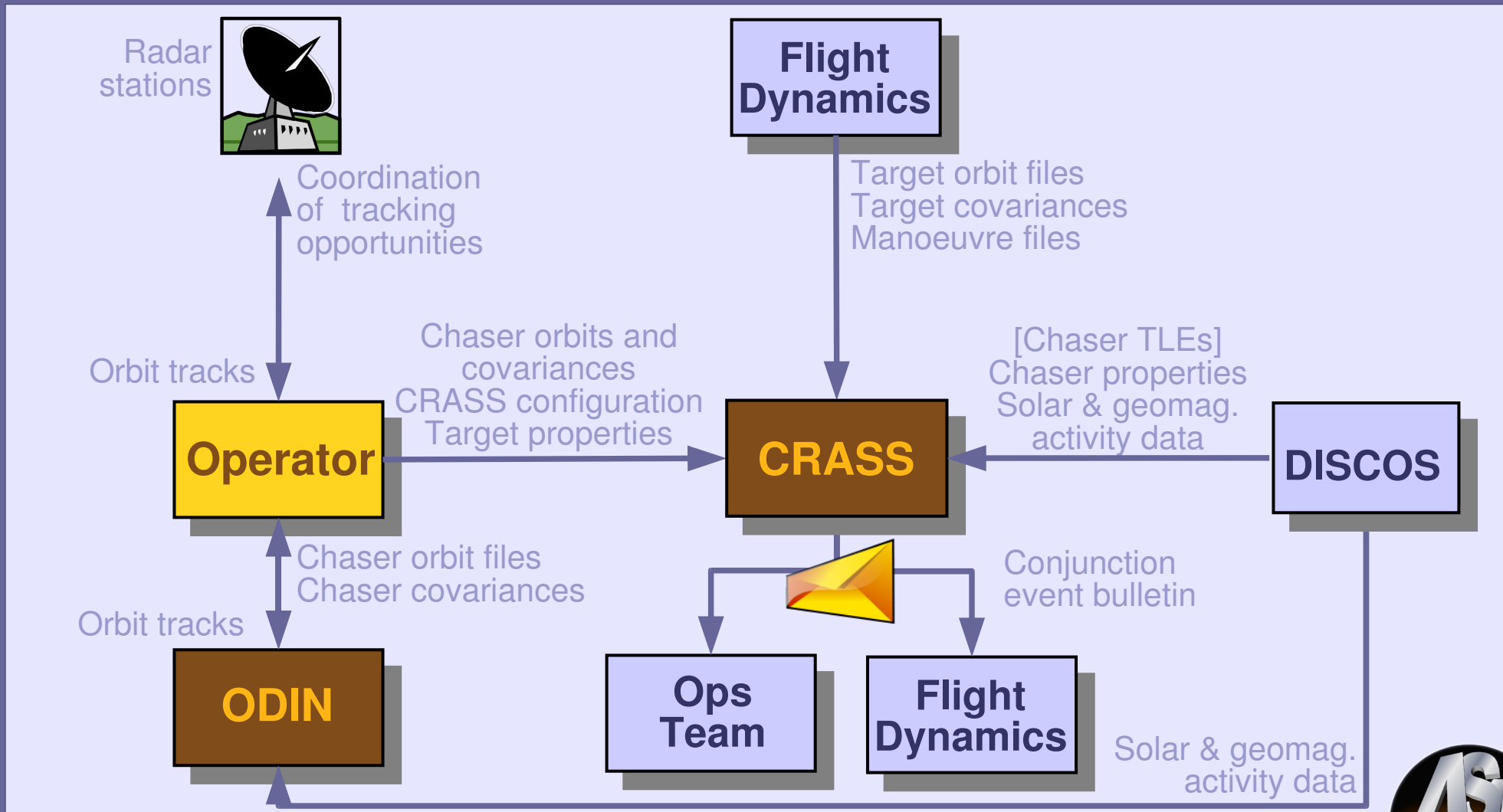
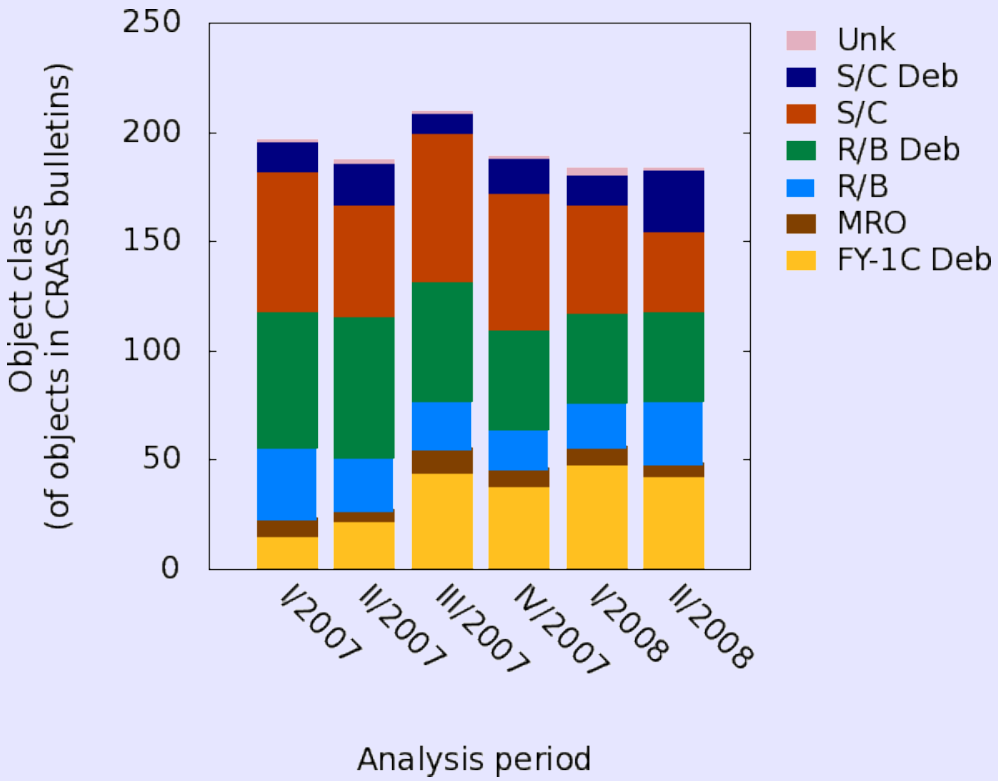
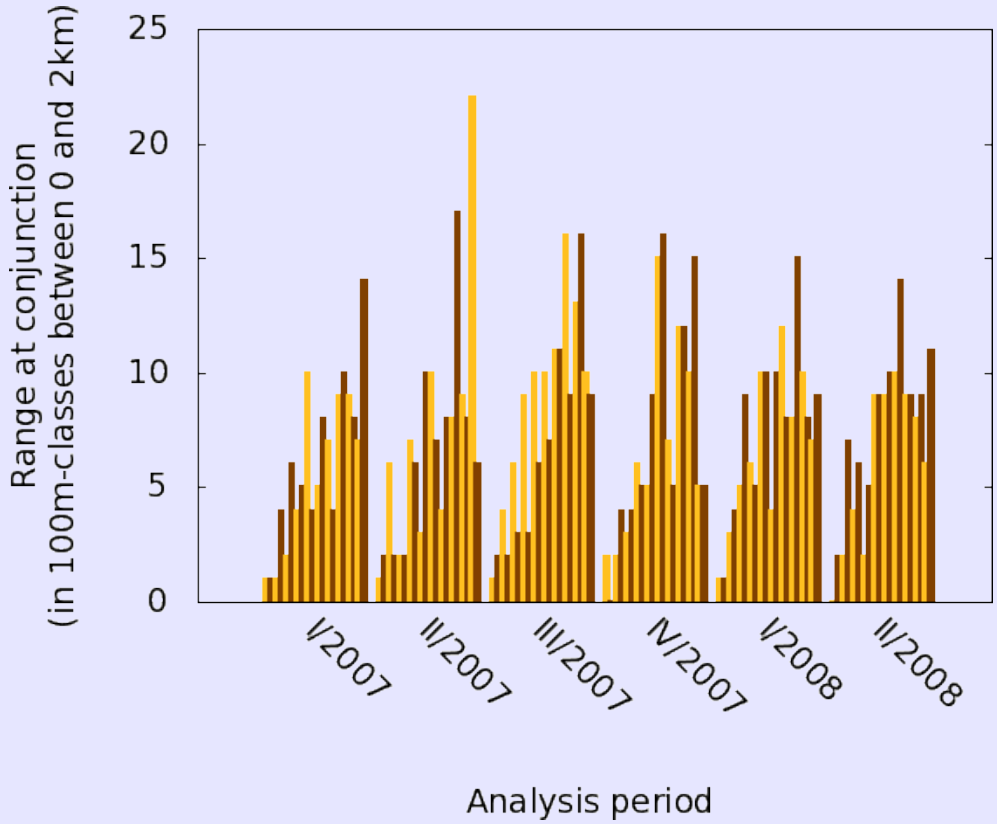
CRASS / ODIN Outline



Conjunction Event Statistics

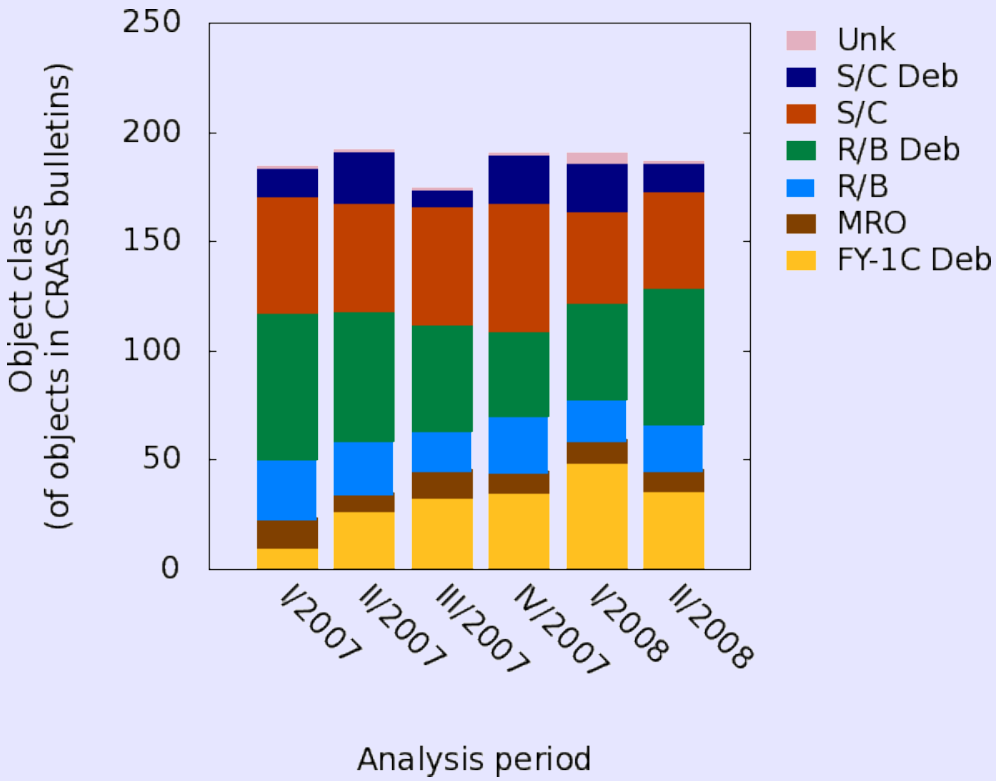
ERS-2

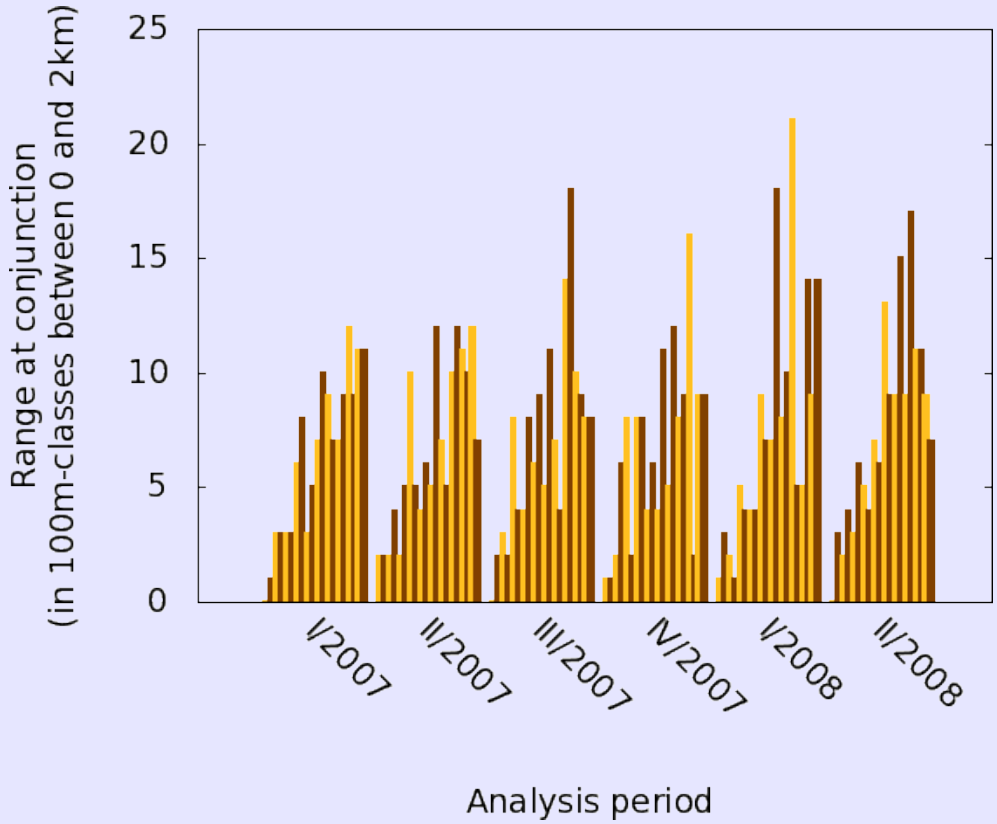




Conjunction Event Statistics

Envisat





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- Scheduled daily analyses and high-risk events
  - Operational service
  - Identified shortcomings

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Operational CRASS service

- 2002 development and installation at Sun/Solaris platform
- 2008 migration to Linux OS
  - 2 identical, parallel installations ensuring (some) redundancy
  - New analysis and visualisation options (basis : GMT, gnuplot, ...)
- Daily email bulletins (7 day predictions)
  - Subscribers for
    - Bulletins and warnings ($P > 10^{-4}$) || ($\Delta R < 300$m)
    - Normal and reduced content volume
- Off-line analyses scheduled by analyst (on request)

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Identified shortcomings

- CRASS : fully automated, redundancy, fall-backs
- Handling of high-risk events : manual → work-intensive
  - Implementation of ODINcl (job scheduler on top of ODIN)
  - Automated procedures facilitating
    - Processing of tracking data
    - Update of ephemerides and co-variances
    - Update of conjunction geometries
    - Generation of collision risk figures

      → Up-to-date picture of situation

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- Automated orbit determination from radar tracks
  - Process
  - Functionalities

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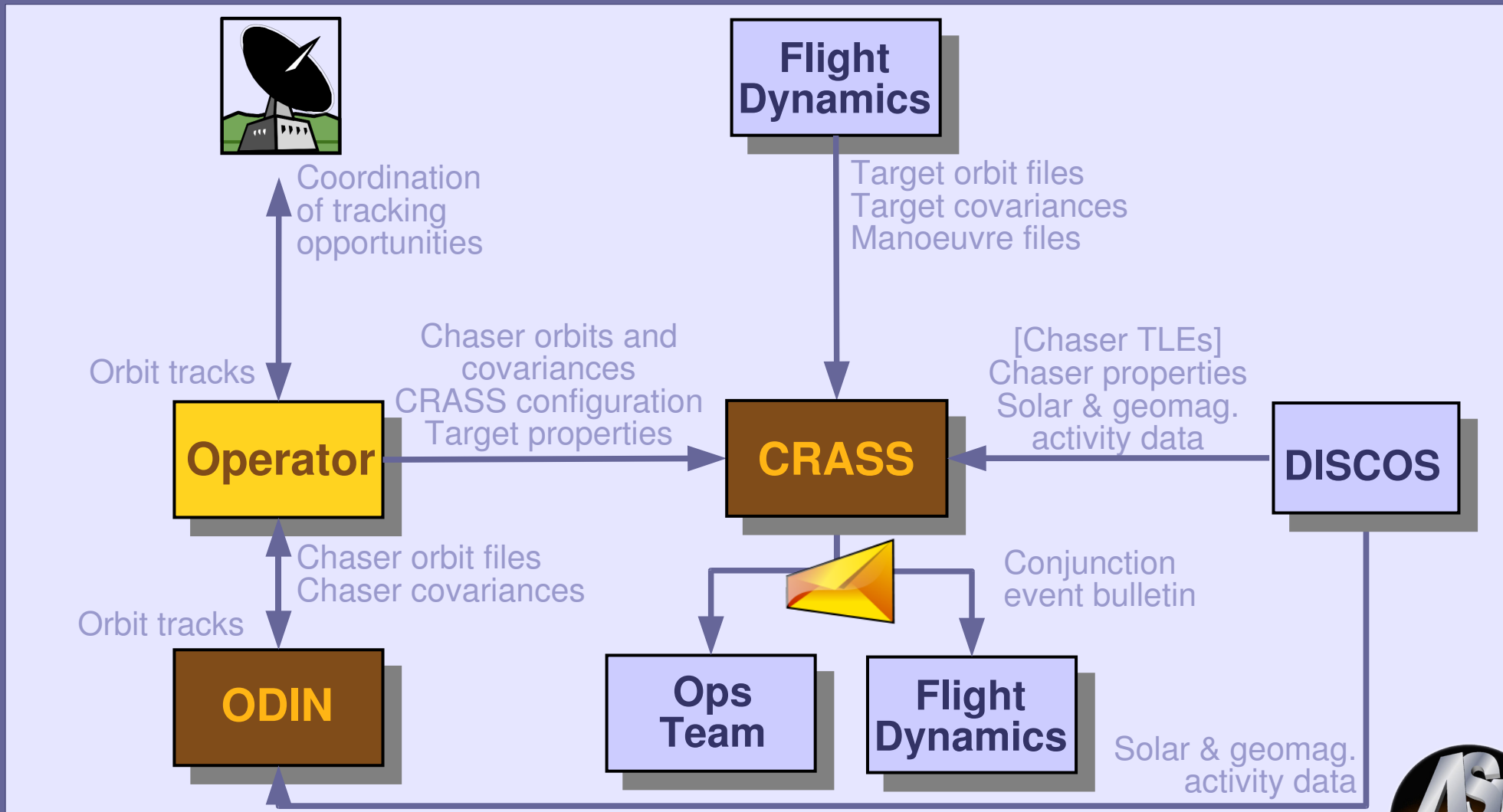
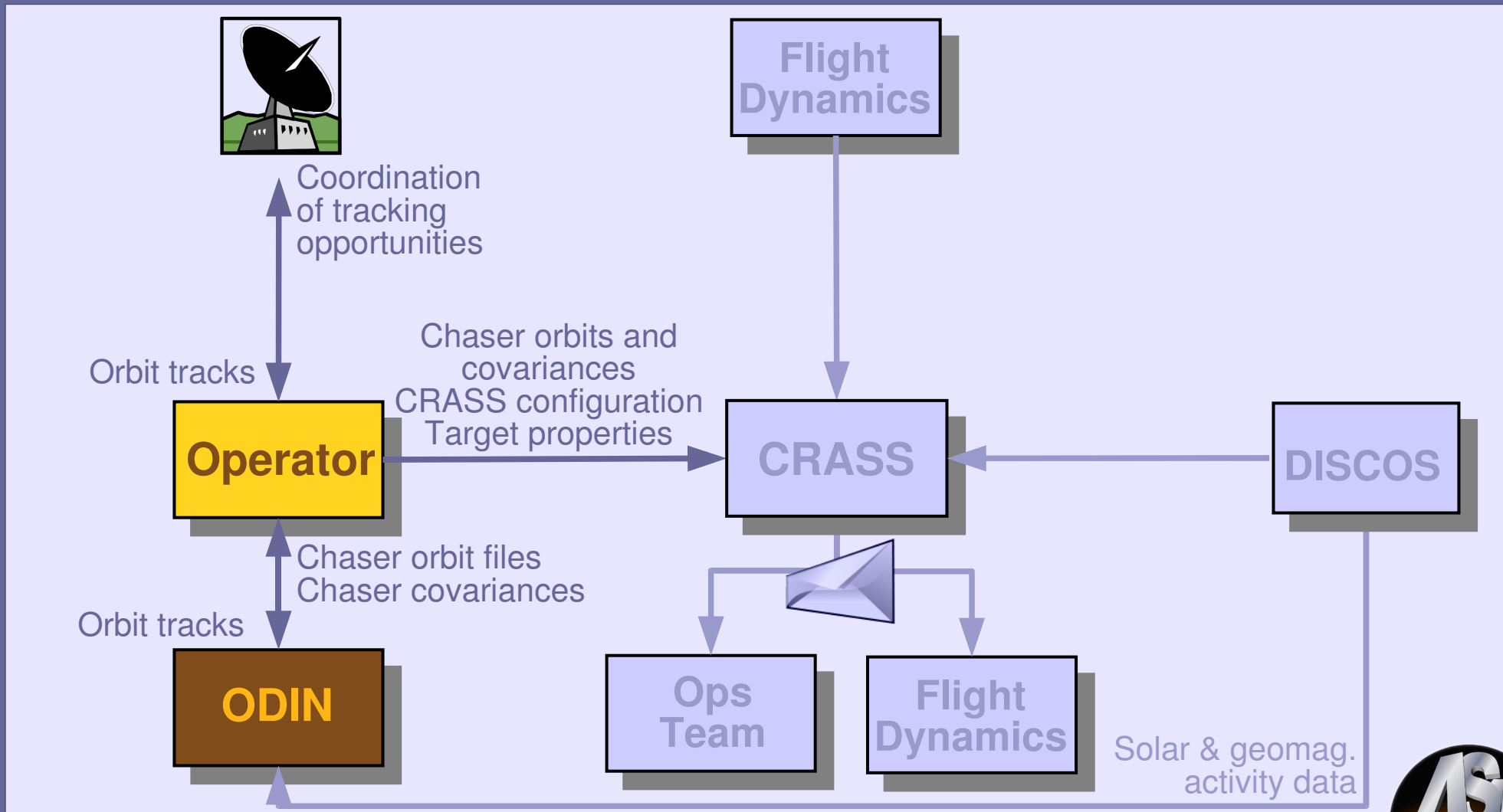
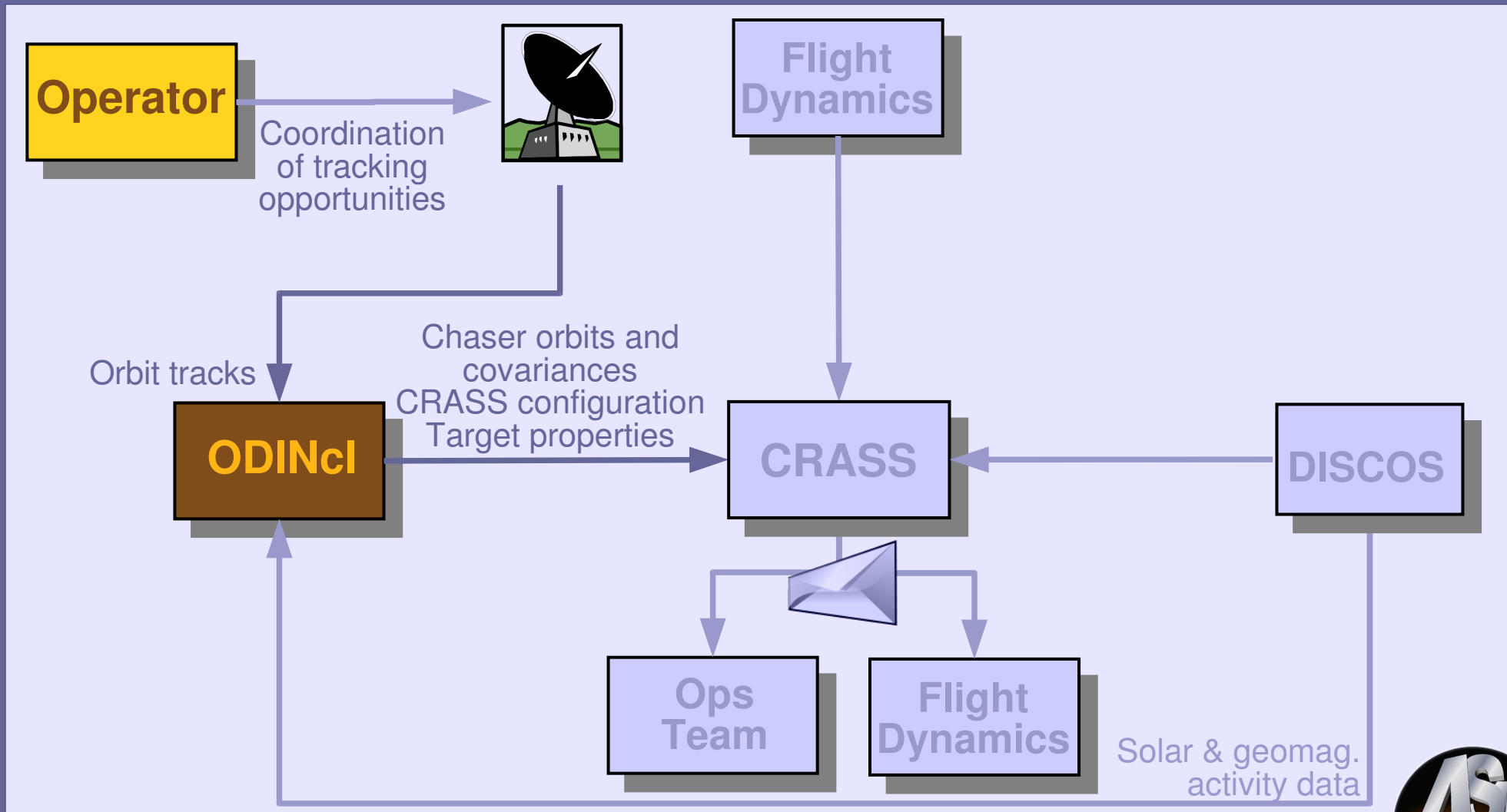
ODINcl process



ODINcl process



ODINcl process



ODINcl functionalities

- ODINcl allows automating all ODIN modules
- Optional : repeated execution of similar analyses
- Significantly decreased risk of operator mistakes
- Performance measure : runtime of orbit determination and subsequent conjunction event re-assessment
  - Manual processing on Sun/Solaris : ~1.5h
  - Automated processing with ODINcl on Linux OS : < 0.5h

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- Automated orbit determination from Radar tracks
- Recent high-risk conjunction events
  - Overview
  - Example1 : COSMOS-1624, 2008-Jan-09
  - Example2 : COSMOS-1486, 2007-Nov-14

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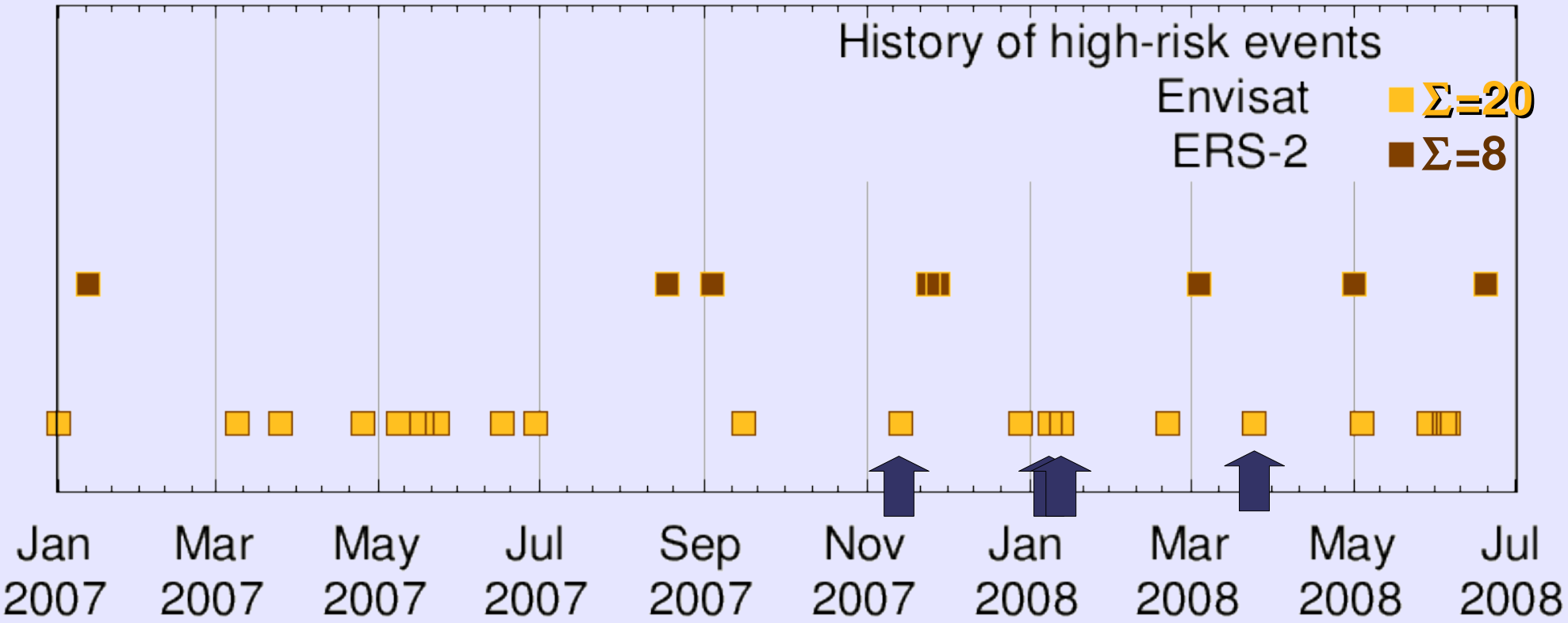
Overview recent events

Jan 2007 – Jul 2008



FGAN tracking data required and processed

... but no performance of avoidance manoeuvres required in period

Example 1

COSMOS-1624, 2008-Jan-09

- Chaser : COSMOS-1624 (15482, 85006A), Strela-2M
  - m =732.31kg ; A =1.77m^2 ; i =74° ; h ~800km
  - Maximum collision probability was determined to be : ~1/1200
- 4 tracks from FGAN on Jan-7 and Jan-8

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Example 1

COSMOS-1624, 2008-Jan-09

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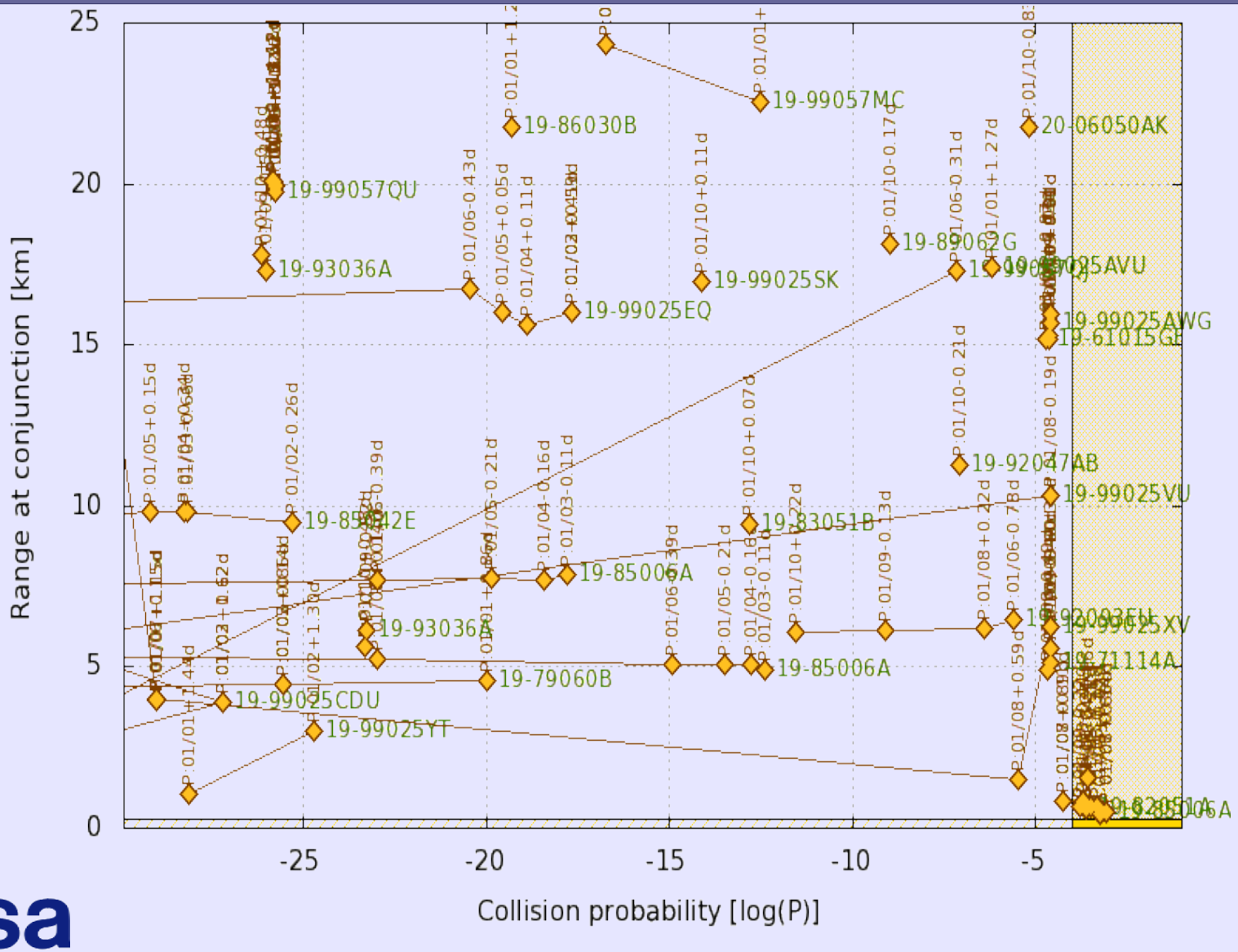
COSMOS-1624, 2008-Jan-09



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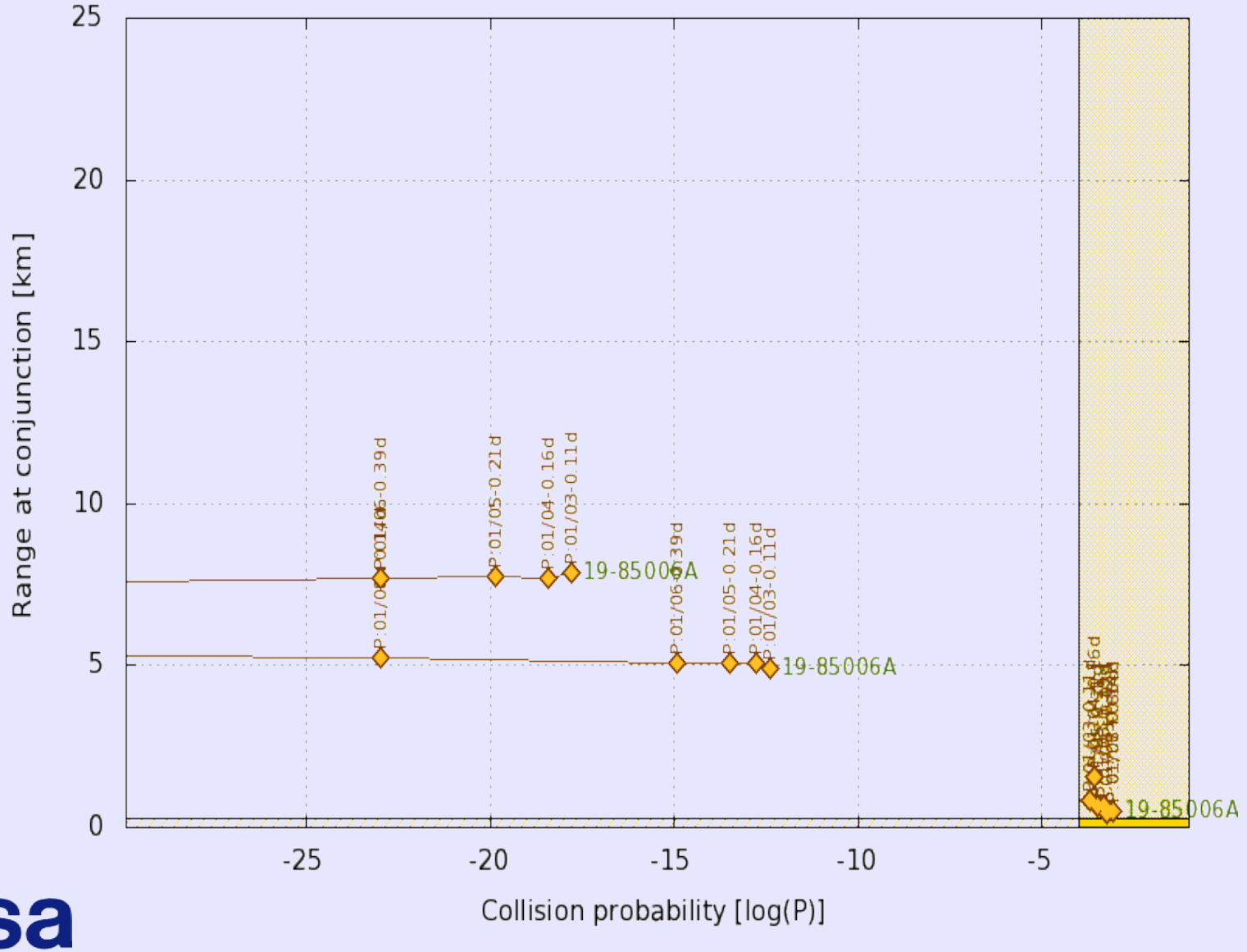
COSMOS-1624, 2008-Jan-09



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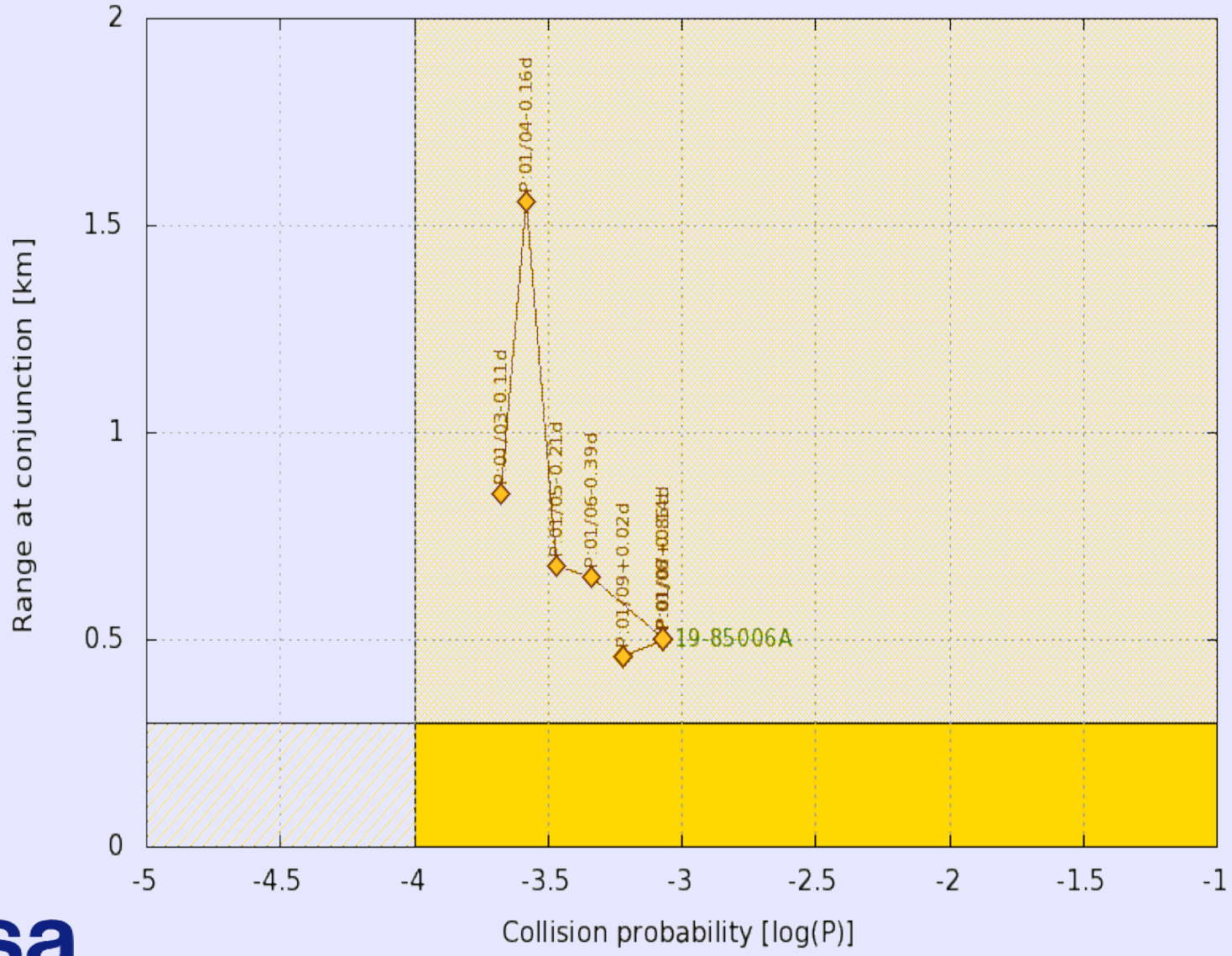
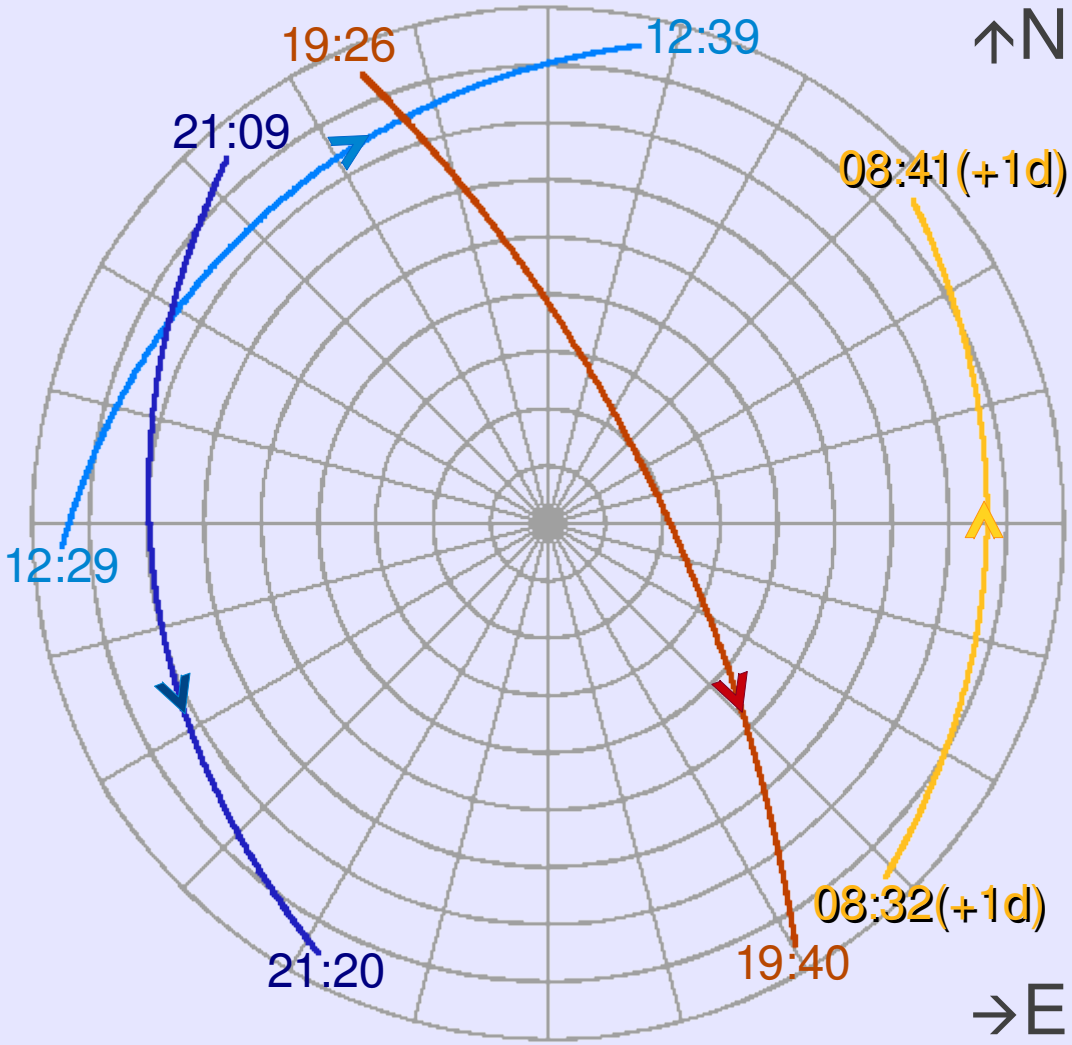


Example 1

COSMOS-1624, 2008-Jan-09

observed passes with TIRA Jan 7 and 8



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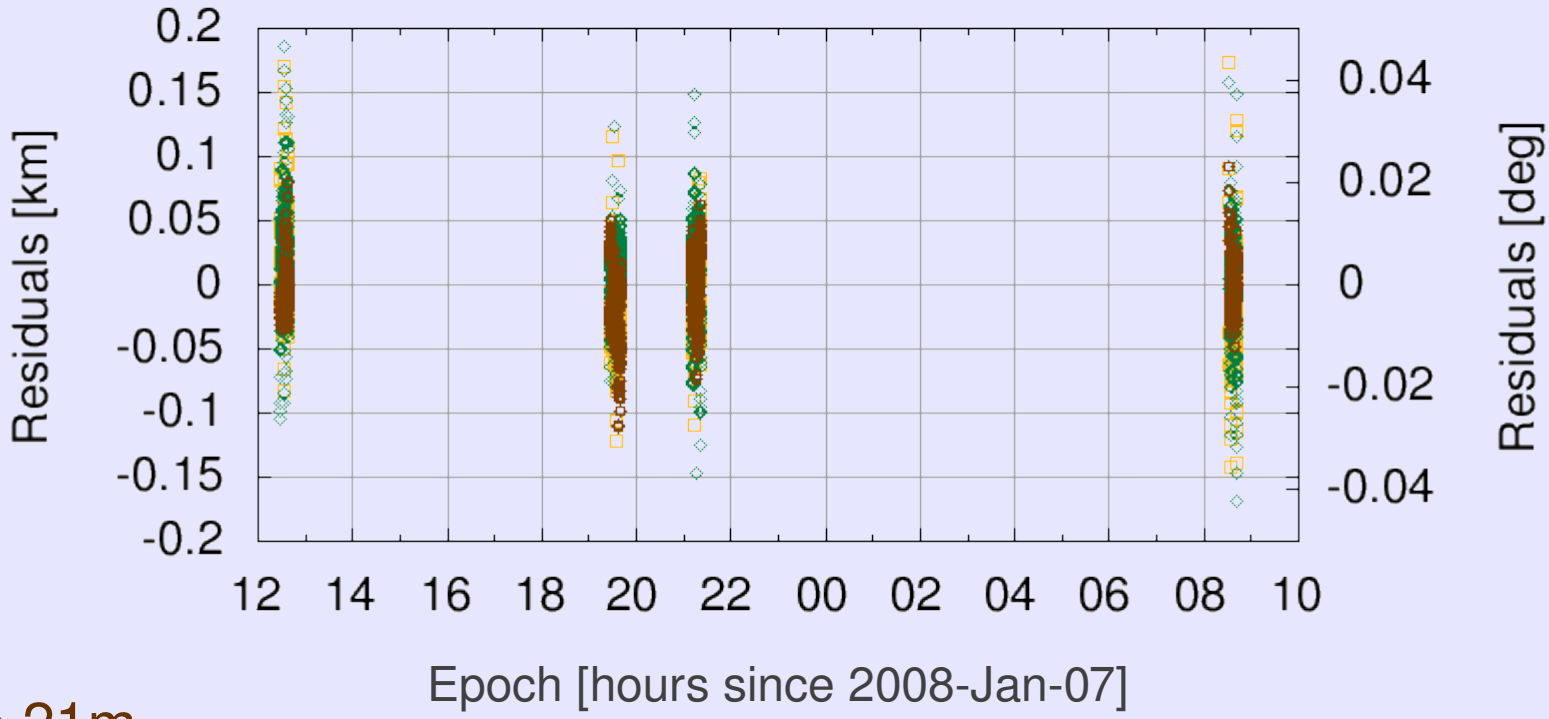
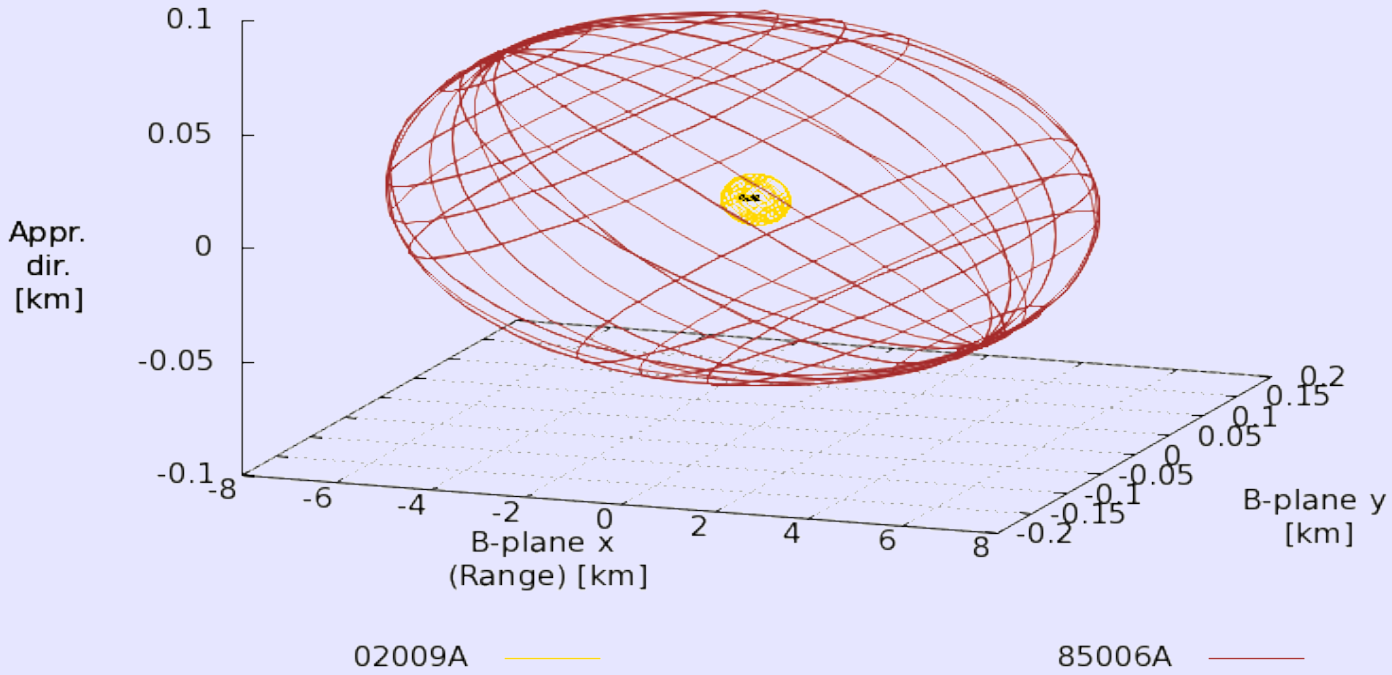


- RMS range 21m
- RMS azimuth 0.009 deg
- RMS elevation 0.009 deg

Example 1

COSMOS-1624, 2008-Jan-09

covariance ellipsoid of position prior orbit determination :

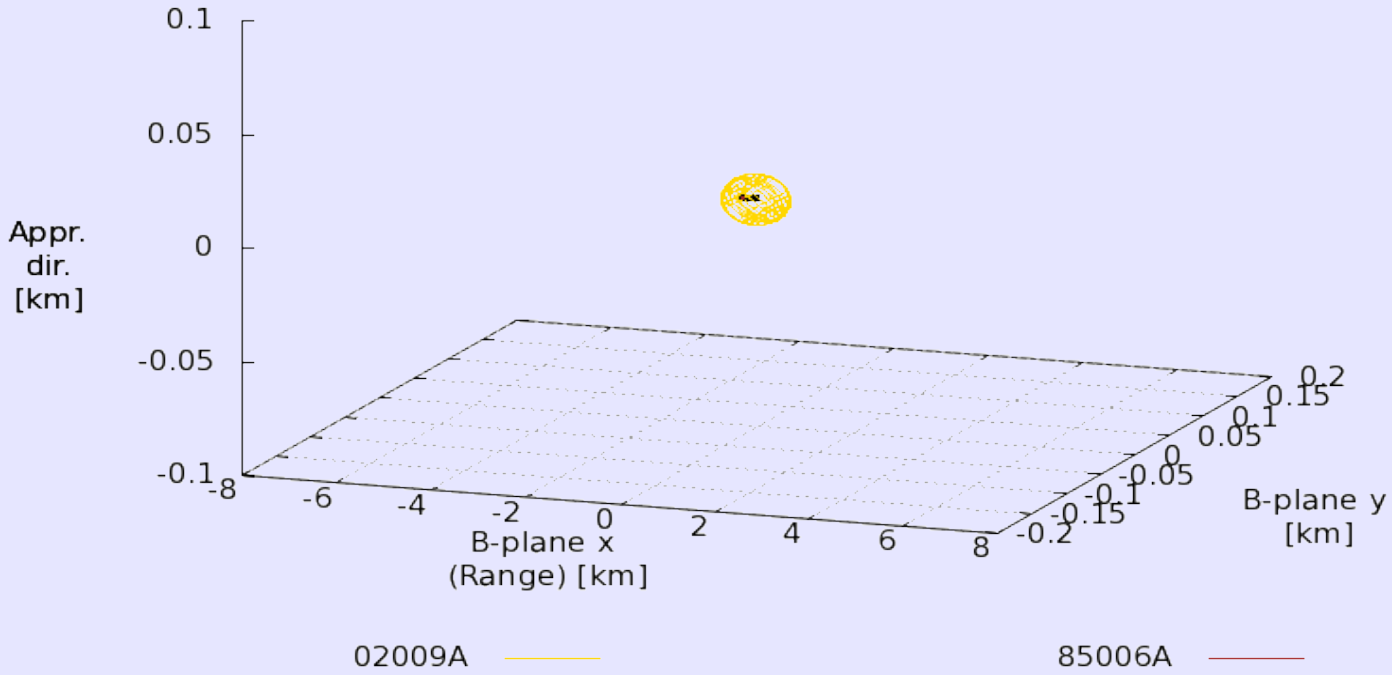


Example 1

COSMOS-1624, 2008-Jan-09

covariance ellipsoid of position after orbit determination :

better by a factor of 100



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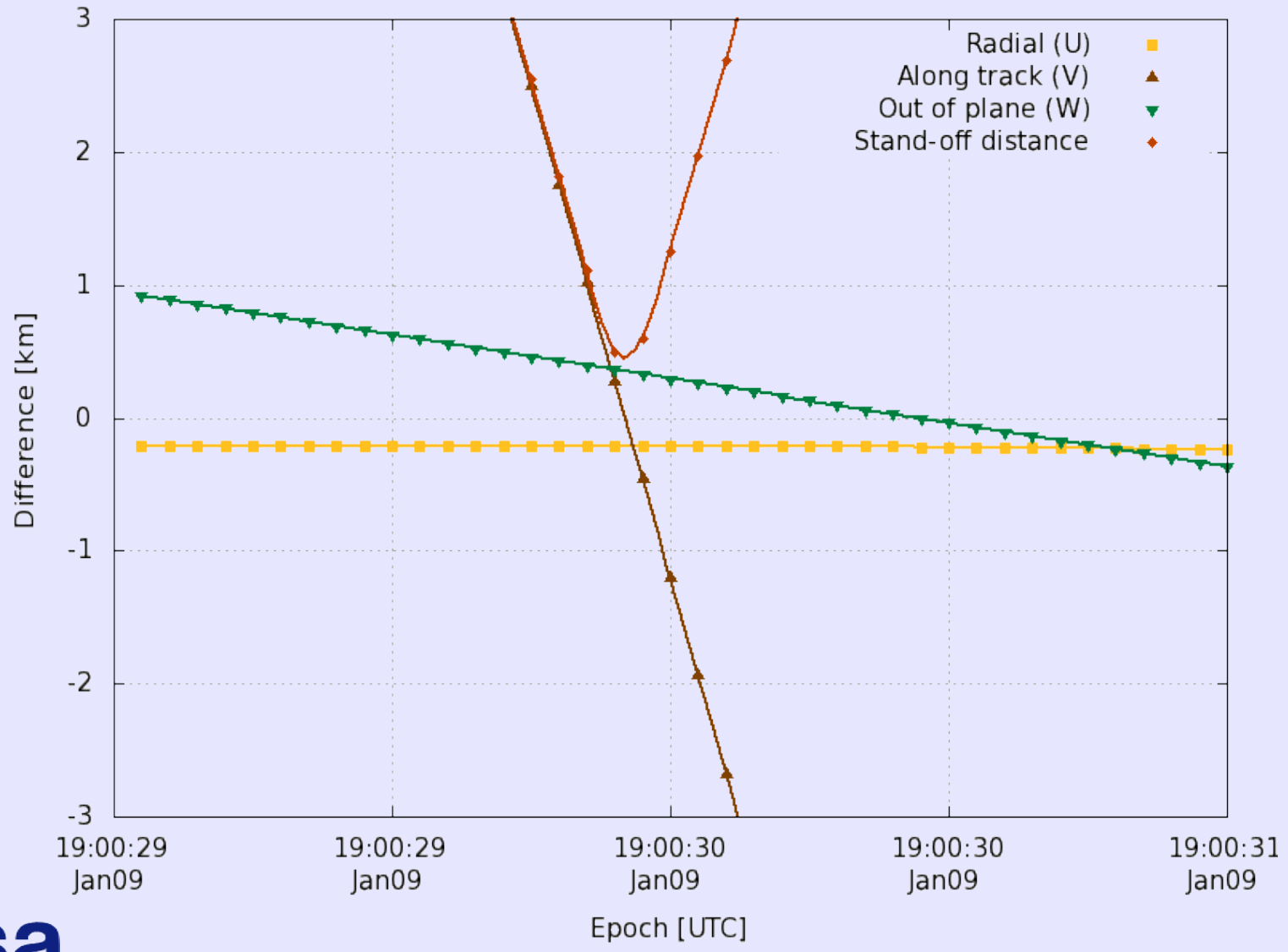

Example 2

COSMOS-1486, 2007-Nov-14

- Chaser : COSMOS-1486 (14420, 83079A), Strela-2M
  - m =732.31kg ; A =1.77m^2 ; i =74° ; h ~800km
  - Maximum collision probability was determined to be : ~1/1100
- 5 tracks from FGAN on Nov-12, starting ~2h after request
  - Orbit determination performed from 4 tracks

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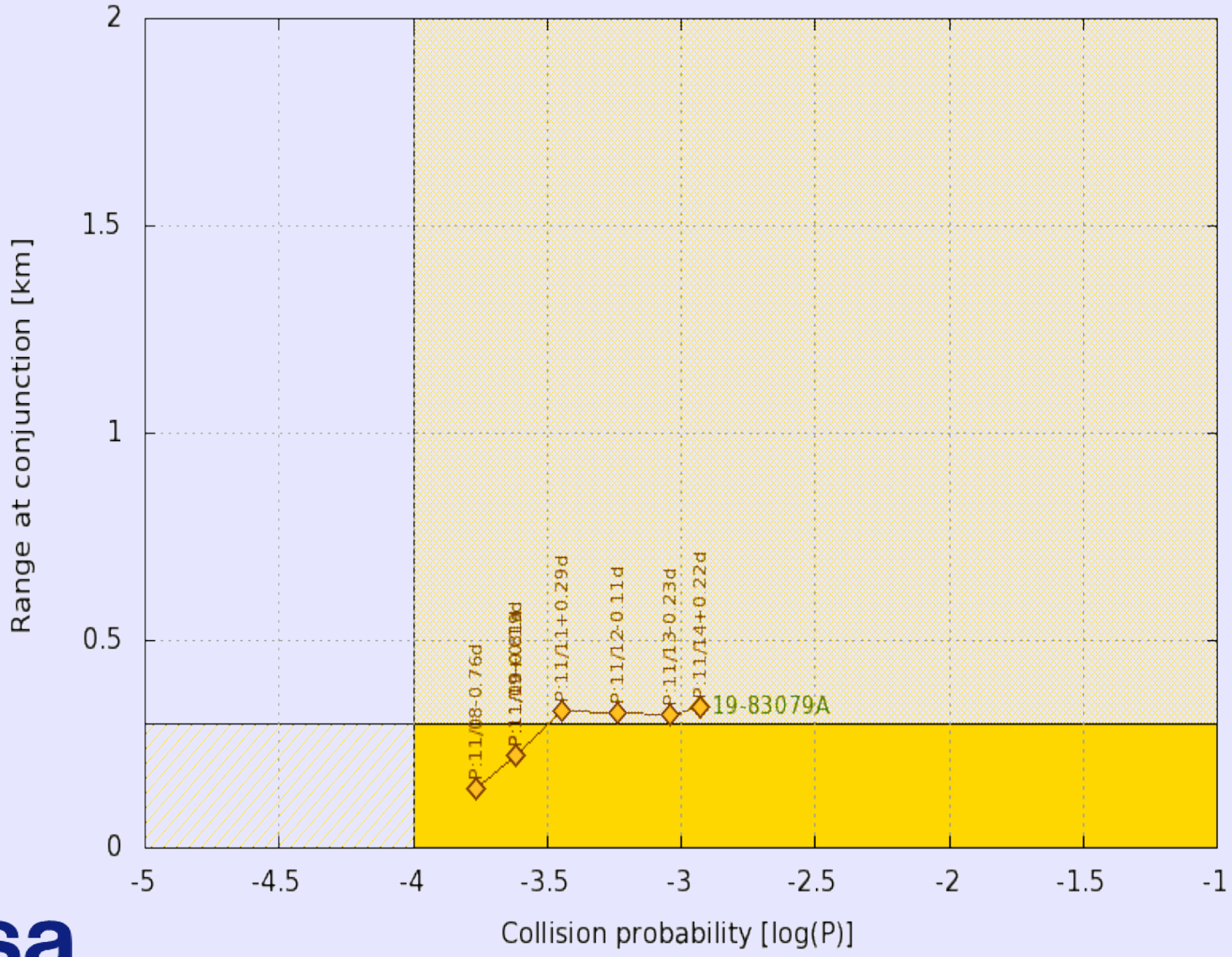
Example 2

COSMOS-1486, 2007-Nov-14



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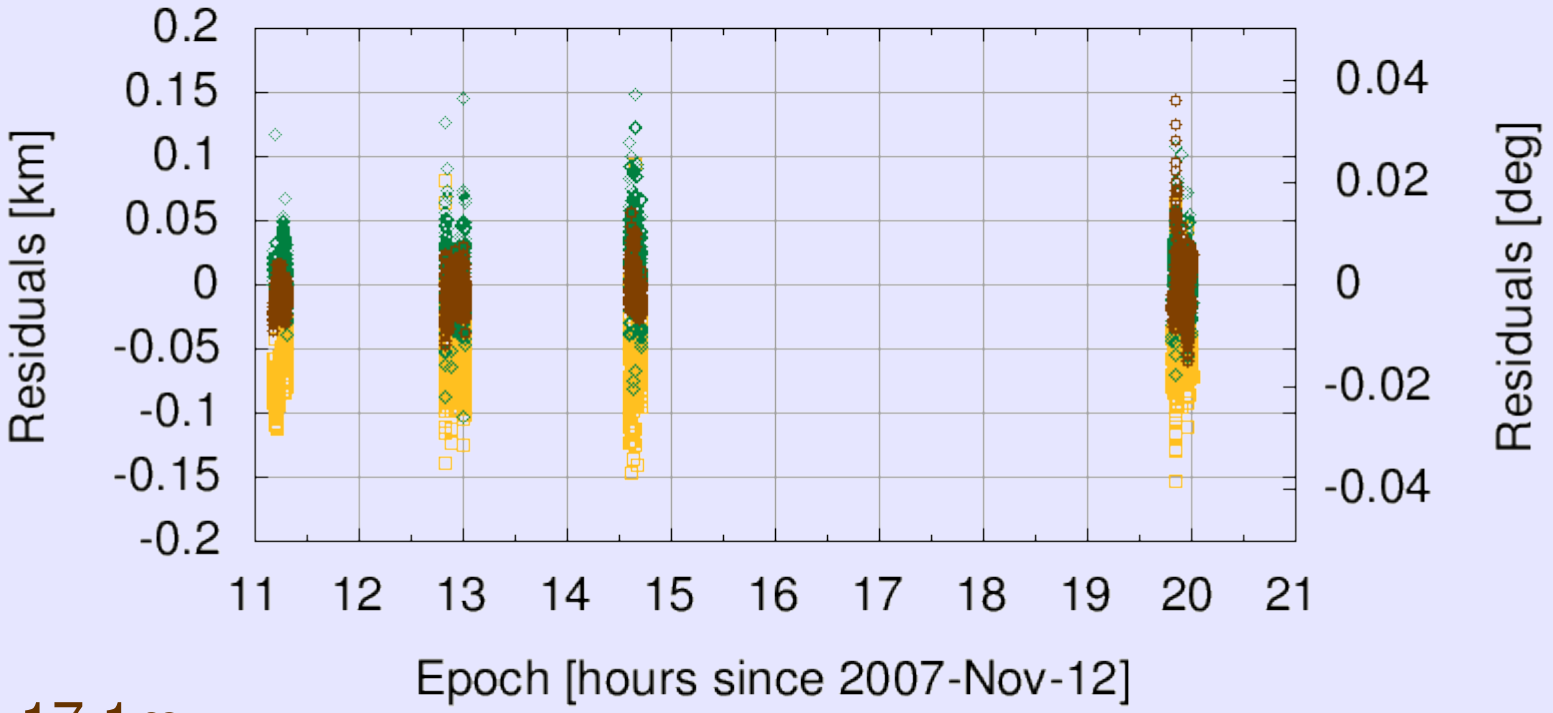
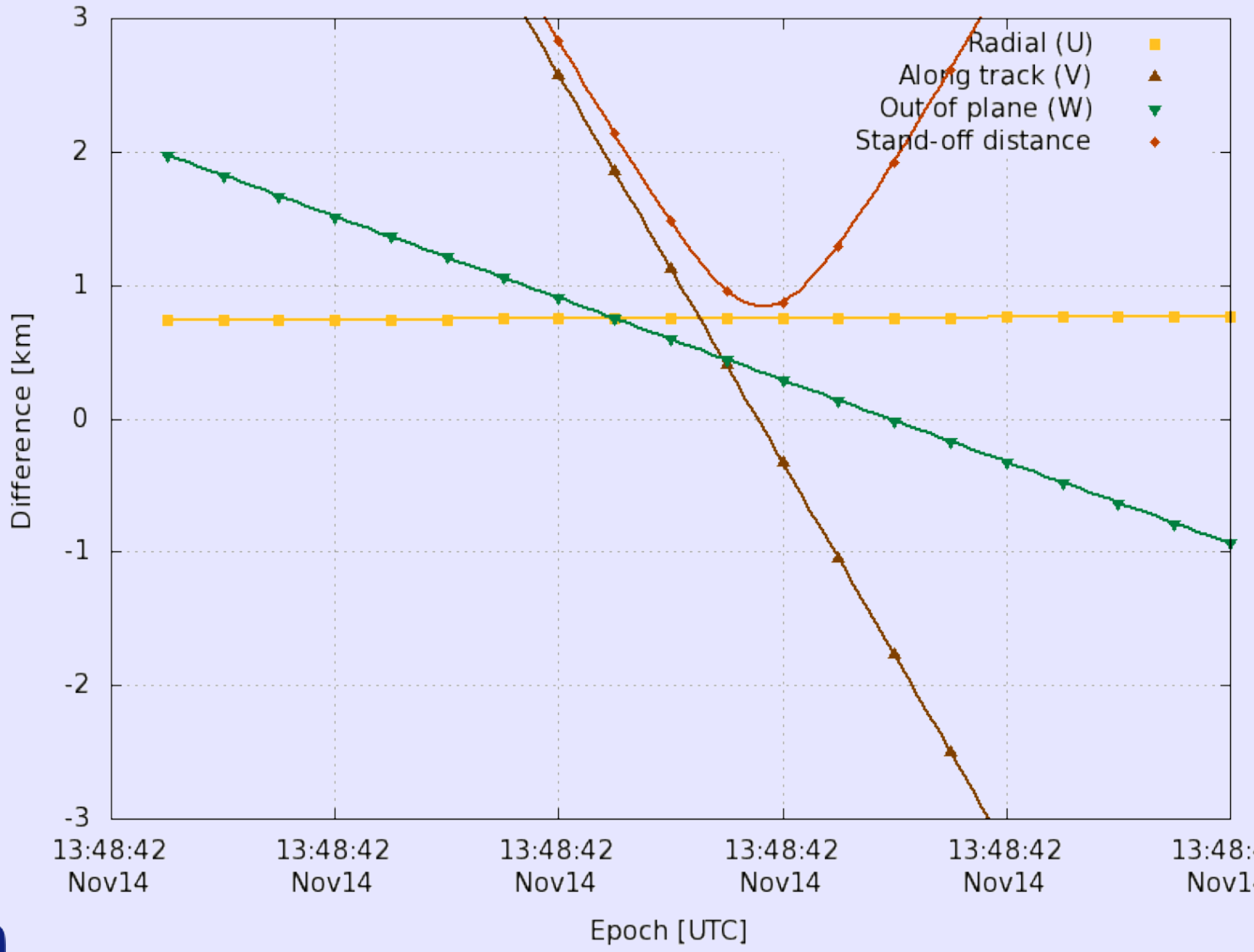


- RMS range 17.1m
- RMS azimuth 0.016 deg
- RMS elevation 0.007 deg

Example 2

COSMOS-1486, 2007-Nov-14

confirmed radial separation of ~0.7km



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Conclusions and Outlook

- Two major tasks for Envisat and ERS-2
  - Conjunction event detection and collision risk assessment daily, using TLE data and empirical covariance information
  - High-risk events may require additional tracking data (FGAN) – avoidance of manoeuvre → improved states and covariances
- Both tasks are highly automated
- CRASS & ODIN : support decisions of space debris analysts and of spacecraft operators
- Current frequency of high-risk event
  - ERS-2 : 5 a^{-1} ; tracking ~1 a^{-1}
  - Envisat : 13 a^{-1} ; tracking ~ 3 a^{-1}

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