CENTRE NATIONAL D'ÉTUDES SPATIALES

Adaptations to changes in Collision Avoidance Operations at CNES for in-orbit satellites

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- CNES and the French MoD
- Concerned satellites, milestones
- Collision Avoidance process
- CNES adaptations
- Operational results
- Tools

SpaceOps workshop
June 16th 2011, Oxford

French SSA activities

- **CIE (Joint Space Command)**
  - Created in July 2010
  - French point of entry for all spatial matters in French Defense
- **CDAOA (Air Defense and Air Operation Command) is responsible for French space surveillance**
  - Operates the French surveillance radar GRAVES
  - Is in charge of coordinating French operational means : CNES, Air Force, DGA
- **CNES, as the French space agency**:
  - represents France at the ESA SSA control board
  - has the responsibility to authorize launching satellites from French Guiana
  - is the state agency responsible for the 2008 Space Operations Act implementation

  and, as the French technical space center,
  - performs the in-orbit control of governmental satellites
  - monitors collision risks and performs collision avoidance maneuvers

CNES and CDAOA have established direct and close operational links

CNES Controlled satellites

- **June 2011 :**
  - **1 GEO satellite (Telecom 2D)**
  - **12 LEO satellites (altitude ~ 600 / 1200 km)**

- **Other LEO to come : Elisa (4), Pléiades,…**
- **ATV : dedicated collision risks organization in direct interface with ISS partners.**
- **Recent end of life activities :**
  - **Spot2 and TC2C in 2009**
  - **Essaim (4 satellites) in October 2010**
  - **Demeter early 2011**

OCC is in charge of collision risk assessment for all CNES controlled satellites

OCC : operational Orbit Computation Center (French name : COO)

- **CNES Collision Avoidance team**
  - **8 flight dynamics specialists (part-time : 6 from OCC + 2 from studies entities)**
  - **24/7 on-call team**
  - **Since July 2007**

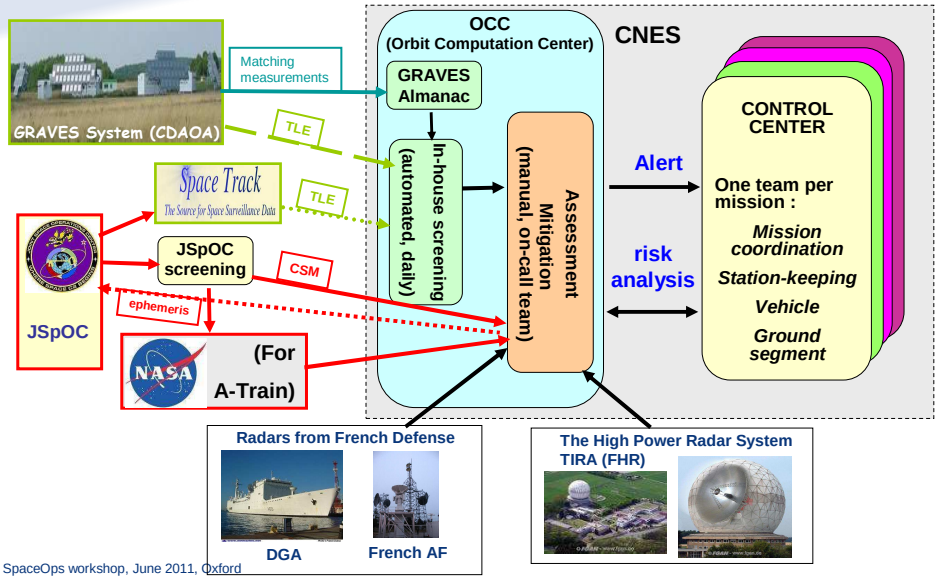
- **OCC other activities :**
  - **Orbit determination: first diagnosis after launch, satellite control center back-up, monitoring of TTC station measurement performance**
  - **Look angles for ground stations: routine (5 satellites daily, ~40 in contingency) and on request**
  - **Atmospheric reentries (mainly through IADC exercises)**

OCC capacity to handle classified data

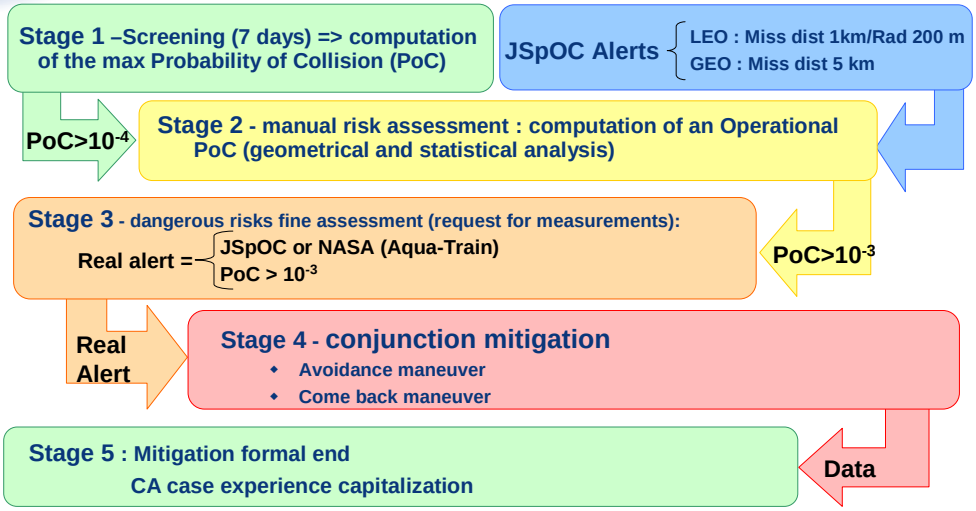
CDAOA and CNES have established direct and operational close link
=> Exchange of classified data

- **Security requirements** are given by CDAOA : dedicated document
- Each CNES collision avoidance team member has **the right level of clearance**
- **Dedicated place** to handle the classified data **without any direct link with outside world**
- **Approved procedures** to enter data and to take out unclassified results
- **CNES security officer** monitors requirements enforcement
- **The entire secure link got approval** before starting its exploitation

CNES CA Process objective for 2011
Information flow



CNES Collision Avoidance Process



2009 operational feedback : Space Track TLE are not suitable for CA

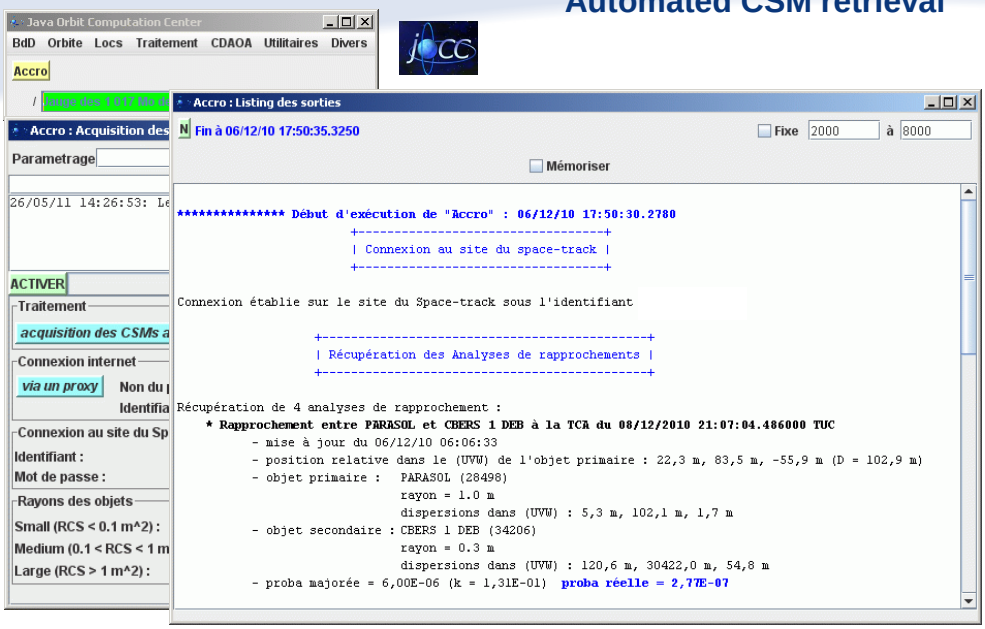
- **Before 2009 : Space Track TLE (**World widely used by the Space Community, except JSpOC)
  - Maximum probability used for detection
  - Best possible use of TLE : an historical analysis provides the observed dispersion of TLE for an object, but :
    - **Dispersion knowledge is not enough**
    - **TLE have non stable "bias" observed with our satellites**
    - **The magnitude of those "bias" can be much bigger than the dispersion**
- **2009 : use of GRAVES data + beginning of JSpOC alerts reception**
  - JSpOC alerts based on precise US catalog (excellent coherence for our satellites between our own orbits and the JSpOC ones)
  - Good coherence for the debris between orbits determined with GRAVES radar data and JSpOC ones (few cases only)
  - JSpOC alerts are hardly ever detected using Space Track TLE
- **Conclusion : need to change CNES process (in 2010)**
  - Stop using Space Track TLE
  - Perform in-house screening with GRAVES data
  - Adapt to fully take JSpOC alerts into account

Major changes in 2010

- **French SSA Center : combined means and know-how of CDAOA and CNES**
  - Signature of a dedicated agreement to collision detection and avoidance between CDAOA and CNES in January 2010
  - Operational link to exchange data and information
  - Operational software dedicated to collision detection and avoidance using GRAVES data

- **CA process adaptations to different kind of JSpOC alerts** : from emails with only radial error component to complete Conjunction Summary Message
  - Until May : radial distance criteria to recommend an avoidance action
  - Since May : additional error components in JSpOC emails
    - New tool developed (PAACS)
      - To compute Probabilty of Collision using JSpOC data. Limitation : only possible when the secondary object has a TLE available on Space Track to get its speed
      - To help collision avoidance maneuver choice
    - Back to probability of collision criteria to recommend an avoidance action
  - Since July : CSM available on Space Track website
    - New tool developed to automate CSM retrieval (ACCRO)
      - To retrieve CSM data
      - To compute Probability of Collision
      - To summarize results
    - New change in operational procedure ? Not necessary.
  - In-house screening : GRAVES data instead of Space Track TLE

Automated CSM retrieval



Operational results
Collision Avoidance process for 18 satellites
(up until October 2010 : 17 LEO + 1 GEO)

2009 : 1241 in-house alerts (473 risks)

- **Potential risks : 44**
  - in-house screening : 18 (PoC > 10^{-3})
  - NASA : 11
  - JSpOC : 15
- **Confirmed risks : 3**
  - 3 avoidance maneuvers (second half of 2009)

JSpOC alerts in 2009 (8 months) 36 risks

- **May : 1**
- **June : 1**
- **July : 1**
- **August : 4**
  - 1 avoidance maneuver (according to available TLE on Space Track website, the performed avoidance maneuver increased the danger)
- **September : 5**
- **October : 9**
  - 1 avoidance maneuver (the performed avoidance maneuver increased the danger according to available TLE on Space Track website)
- **November : 5**
- **December : 10**

2010 (first 3 months)

381 in-house alerts (148 risks)

- **Potential risks : 14**
  - in-house screening : 3 (PoC > 10^{-3})
  - NASA : 0
  - JSpOC : 11 (out of 18 risks)
- **Confirmed risks : 5**
  - 5 avoidance maneuvers (from JSpOC alerts only)

Too many maneuvers
It could not last for long

Aqua-Train

Operational results
Collision Avoidance process for 18 satellites
(up until October 2010 : 17 LEO + 1 GEO)

July 2010 – December 2010

in-house alerts (GRAVES TLE) : 48 risks
JSpOC alerts : 32 risks
NASA alerts : 6 risks

- **Up to stage 3 with orbit refining : 19 risks (only from in-house or NASA alerts, JSpOC alerts being received "too late")**
  - Extra measurements on secondary : 6 risks
  - NASA : 5 risk (1 was also in-house risk)
  - JSpOC support : 1 (GEO), 2 (LEO)
- **Confirmed risks : 3**
  - 1 avoidance maneuver
  - 2 station-keeping maneuver changes

May 2010

- **Additional error components in JSpOC alerts**
  - In most cases, it allows computation of Probability of Collision
  - **Our number of avoidance maneuvers performed since their reception is at least divided by 2 (only 1 avoidance maneuver in June)**
- **Official changes in CNES operational CA procedure**
  - Outside alerts : JSpOC and NASA
  - In-house alerts : GRAVES data

July 2010

- **CSM are available on Space Track Website**
  - Probability of Collision can be computed
  - Not a noticeable change in our number of avoidance maneuvers (after May 2010)

Operational results
Collision Avoidance maneuvers

	TCA	secondary object	maneuver date (UT)	maneuver	come back maneuver	first alert	alert confirmation	PoC	distance (m)
TLE	17/01/2007 08:43	unknown		SK man modif		NASA		1.8*10-2	43
	21/02/2007 02:03	CZ-4 debris	20/02/200717:03	da - 40 m	yes	US TLE		1*10-3	
	25/06/2007 13:39	TITAN 3C debris	25/06/2007 12:49	da + 100 m	yes	US TLE		1*10-2	
	15/10/2008 09:47	INTELSAT 4A-F6 debris		SK man modif		US TLE	TAROT		5000
	20/10/2008 10:59	FENGYUN 1C debris		SK man modif		NASA		2*10-2	80
	11/12/2008 05:19	SL-3 debris		SK man modif		US TLE	TIRA	2*10-3	
JSpOC email	11/08/2009 06:04	FENGYUN 1C debris	11/08/2009 03:37	da + 100 m	yes	JSpOC email			865 (radial 8)
	30/09/2009 10:54	FENGYUN 1C debris	29/09/2009 20:52	da + 35 m		NASA		6.3*10-2	9
	23/10/2009 18:23	SL-08 debris	23/10/2009 17:33	da + 100 m	yes	JSpOC email			12 (radial 2)
	14/02/2010 12:59	FENGYUN 1C debris	14/02/2010 07:00	da - 35 m		JSpOC email			739 (radial 13)
	16/02/2010 03:22	COSMOS 2251 debris	16/02/2010 00:52	da + 85 m (SK)		JSpOC email			621 (radial 25)
	05/03/2010 15:39	FENGYUN 1C debris	05/03/2010 02:20	da - 60 m		JSpOC email			392 (radial 84)
	15/03/2010 19:36	SL-16 debris	15/03/2010 02:22	da + 15 m		JSpOC email			490 (radial 66)
	29/03/2010 03:51	COSMOS 2251 debris	28/03/2010 23:41	da + 40 m	yes	JSpOC email			558 (radial 14)
	21/04/2010 06:13	DELTA 1 debris	21/04/2010 03:43	da + 18 m		JSpOC email			289 (radial 32)
	23/04/2010 12:14	COSMOS 2251 debris	22/04/2010 20:43	da + 21 m		JSpOC email			145 (radial 100)
	01/05/2010 19:01	unknown	01/05/2010 18:10	da - 30 m		JSpOC email			180 (radial 58)
	19/05/2010 06:51	SL-18 debris	19/05/2010 06:02	da + 40 m		JSpOC email			936 (radial 60)
	06/06/2010 23:32	unknown	06/06/2010 22:42	da - 52 m		JSpOC email			212 (radial 34)
CSM	09/10/2010 14:44	SL-18 debris	08/10/2010 11:47	da - 50 m		JSpOC CSM		3*10-3	
	14/11/2010 19:25	SL-3 debris		SK man modif		GRAVES	JSpOC	1.4*10-3	
	23/11/2010 03:12	CZ-4 debris		SK man modif		NASA		1.6*10-3	2778 (radial 33)
	05/02/2011 02:44	FENGYUN 1C debris	05/02/2011 00:14	da + 50 m	yes	JSpOC CSM		4*10-3	142 (radial 24)
	19/02/2011 20:47	OV2-1 debris	18/02/2011 15:58	da + 10 m (SK)		NASA	JSpOC CSM	8*10-6	185 (radial 34)
	28/04/2011 15:27	PSLV debris	28/04/2011 14:37	da + 87m		JSpOC CSM		1.310-3	288 (radial 8)

Operational software JOCC

- **JOCC :**
  - **Java Orbit Computation Center**
  - **Dedicated to collision detection and avoidance using GRAVES data**
  - **Multiple users (CNES and CDAOA)**
- **GRAVES Almanac : catalog of precise orbits for all the objects seen by GRAVES obtained with orbit restitutions using matching GRAVES measurements**
- **Creation and maintenance of GRAVES Almanac.**
- **In-house screening using the Almanac to detect conjunctions.**

On going activities

- **Improvement of risk analysis methods**
  - Take into account feedbacks from the reception of CSM : **optimization of CSM retrieval**
  - **Improve MMI** for Conjunction Assessment and Collision Avoidance
  - **Characterize the ephemeris accuracy** as part of routine operations
- **Optimization of GRAVES data use for screening and mitigation**
  - Creation and maintenance of **GRAVES Almanac**
  - In-house screening using Almanac : **produce alerts** (CSM, later CDM format)
- **Observation means**
  - Emphasize the need to **secure availability of Surveillance data**
  - Promote access to tracking measurements for close approach assessment
- **International exchanges**
  - **Ephemerides shared with JSpOC** to get relevant alerts (around station-keeping maneuvers)
  - Comparisons of results with different methods