ALSAT-2A MISSION: EXPERIENCE OF TWO YEARS OF OPERATIONS

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Abstract: *ALSAT-2A is the second Earth Observation spacecraft for Algeria and it is the first satellite of a constellation composed of ALSAT-2A and ALSAT-2B. It has been launched by PSLV-C15 on 12th July 2010 from Sriharikota, Chennaï (India) at 03h52' UT. On 21st July, the satellite has been placed on its mission orbit. This was the starting point of the routine operations to be performed daily by Algerian Space Agency's Flight Dynamics team. This paper presents the main events during the 2 years of operations. It namely describes the Orbit maintenance maneuvers that were performed in the past months for Ground track correction. It also highlights the treatment of several Conjunction Summary Message CSM provided by United Sates Joint Space Operations Center (JSpOC) and the first experiences of CDS/ASAL with avoidance maneuvers using appropriate developed tool called CSMAT .*

Keywords: *ALSAT-2A, CSMAT, Avoidance maneuver, collision probability, CSM.*

1. Introduction

ALSAT-2A is the second Earth Observation spacecraft for Algeria and it is the first satellite of a constellation composed of ALSAT-2A and ALSAT-2B. ALSAT-2B is planned to be launched on 2014 and will be phased with ALSAT-2A.

Figure 1. View of ALSAT-2A spacecraft

The reference mission orbit of ALSAT-2A is a phased Sun-synchronous orbit with 14 + 19/29 revolutions per day repetitivity of ground track (altitude over equator around 670 km). The target orbit reached at the beginning of life has been optimised to avoid corrections of the Local Solar Time (out of plane maneuver) during 5 years. This orbit is defined by a semi-major axis of 7048 km and an inclination of 98.23 deg. At the end of the LEOP phase, the SK initial conditions were ground track (GT) error = +39 km and Local Solar Time (LST) = 21.30 PM.

Since 21th of July 2010, the operations are performed from ALSAT-2 ground segment located in Ouargla (Algeria). The CDS/ASAL operation team is now fully autonomous to control and monitor nominally ALSAT-2A and is also able to handle anomaly situation, analyze telemetry, and correct the anomalies.
During the 2 first years of operations many Orbit Control Maneuvers OCM were executed: 10 of them were regular station keeping OCM performed for ground track corrections and 2 OCM were performed as emergency collision avoidance maneuvers. The last station keeping OCM has been performed on September 2012 for ground track correction. The different steps and the strategy used for ALSAT-2A station keeping are described in section 2.

Regarding the emergency maneuvers, two avoidance maneuvers were performed due to the space objects close approach to ALSAT-2A on April and July 2012. CDS/ASAL had been informed of this risk by JSpOC (Joint Space Operations Center) who sent conjunction awareness messages. In last years, due to the increasing population of uncontrolled man-made objects orbiting the Earth, in particular at LEO altitudes, the conjunctions and the risk of collisions between a satellite and space debris or another satellite becomes important [1]. Since September 2010, CDS/ASAL receives from JSpOC the collision awareness regarding ALSAT-2A as soon as the global miss distance is below 1 km or the radial distance is less than 200 meters. In order to retrieve, analyze the awareness collision message and to perform avoidance maneuver if necessary, CDS team had developed a tool called Conjunction Summary Message Analysis Tool (CSMAT). The description and the strategy followed by the flight dynamics and mission team for CSM treatment are described in section 3.

2. Station Keeping Orbit Maintenance

2.1. Orbit Maintenance Strategy

The orbit maintenance strategy shall not disturb the payload operation. Therefore, the SK shall be optimized to plan only necessary maneuvers. The two parameters to be considered for SK are Ground Track error and Local Solar Time error. Ground Track of the orbit is defined as the locus of points projected on the Earth's surface directly "beneath" the spacecraft orbit.
Due to the time varying nature of the perturbations on the orbit, deviations from the reference orbit lead to ground track drift. To understand this, consider the orbit as it crosses the equator (called ground track error), as the earth rotates from one node crossing to the next the ground track moves westward. If the orbital period is exactly right, successive node crossings match successive reference nodes. If the period is too short, the Earth does not rotate quite far enough, and the true node falls eastwards of the reference node. If the period is too long, the earth rotates too far, and the true node falls westwards. After several orbits, the ground track moves further and further to one direction or another and a ground track drift develops. Ground track maintenance maneuvers must be performed to maintain the ground track within a predefined control window around the reference ground track. For ALSAT-2A, this window is ±40 km. as shown in “Fig. 2.”

For the Local Solar Time, no corrections of inclination will be performed as explained in [2].

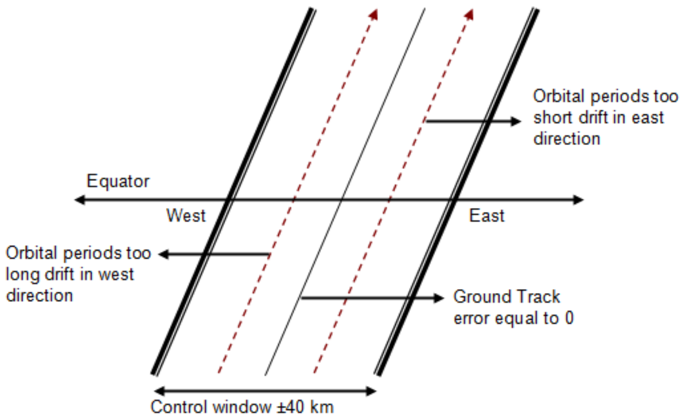

Figure 2. Ground track drift, measured at the equator

2.2. Orbit Maintenance OCM

The operators performed SK long-term prediction based on weekly basis to check evolution of ground track and local solar time. The ground track and local solar time real evolutions since the LEOP have demonstrated that with the real solar activity and the others perturbations, the maneuver size and epoch are not exactly the predicted values. In fact the semi-major axis decreases not as expected. Then the maneuver is refined, implemented and simulated before being sent to the spacecraft. After the maneuver, OCM performance is assessed in order to compute calibration coefficient that will be used for next maneuver.

Since the end of transfer phase, 10 station keeping OCM maneuvers have been performed. Regarding the last couple of OCM maneuvers, to prevent ALSAT-2A from exiting the Ground Track window on the east side, two maneuvers to increase semi-major axis have been planned. The date selected to perform the correction on the semi-major axis was September 18th, 2012. So, three days after the initially calculated date. This delay is voluntary authorized to allow to satellite team to finish their maintenance operations on satellite.

On Spetember 17th, 2012, the maneuver has been computed in terms of size, start date, duration and all the related mission and satellite constraints have been checked. Then the corresponding satellite Tele-command plan has been generated and uploaded.

A correction of 728 m on the semi-major axis has been performed. To correct the eccentricity as well, the maneuver was divided into 2 OCM of +296m and +432m. These maneuvers were designed to be robust to a 5% maneuver realization uncertainty. The simulation of evolution of Ground Track error after maneuvers is depicted in Fig. 3. The programmed maneuvers are summarized in Tab.1.

Table1. Summary of station keeping maneuvers

	Centroid epoch	ΔV_T (m/s)	ΔV_W (m/s)	Declination (deg)
OCM1	2012/09/18 01:30:00.000	0.1661068866	0.0000000000	0.00000
OCM2	2012/09/18 03:50:47.434	0.2225327740	0.0000000000	0.00000

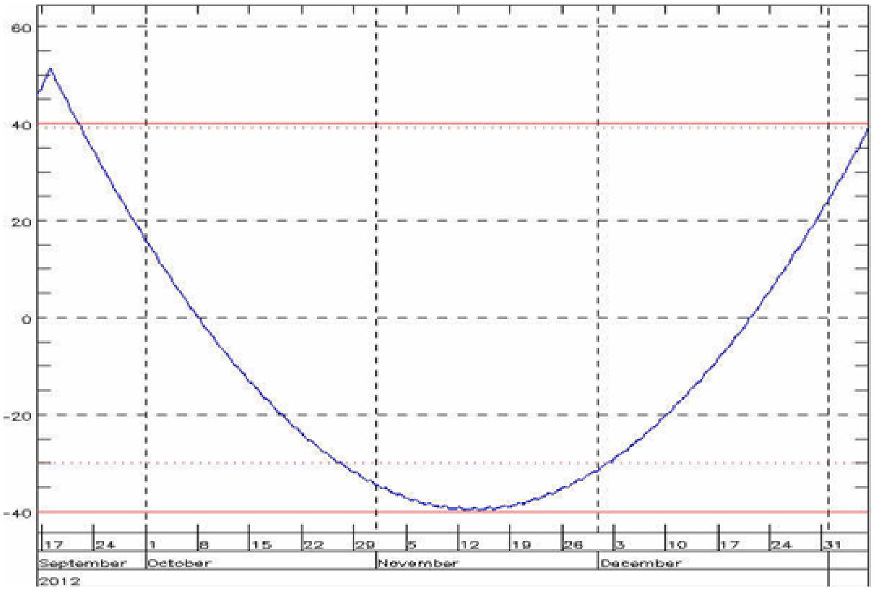

Figure 3. Predicted evolution of ground track error after orbit maintenance OCM

As post maneuvers activities, the efficiency of the maneuvers based on the localization measurements are estimated. The calibration coefficient is then used for the computation of the next OCM. Also the remaining propellant mass after thrust is estimated. Since the end of transfer, the remaining propellant is currently around 2.988kg which was sufficient for orbit maintenance over 10 years. So, 173g has been consumed since end of transfer.

The experience has demonstrated that when the commanded OCM maneuvers were assumed to thrust only in the tangential direction, some transverse components were observed after execution. They are the same order of magnitude as the tangential component as the maneuvers were small [2].

To be more accurate, the method used to determine the calibration coefficient is the Graphical Method, which is recommended during LEOP phase of ALSAT-2A and for the satellite THEOS [1]. The main idea is to graphically compare the mean semi-major before and after the maneuver using the ephemeris before and post maneuver. From this method, the semi-major axis increase was about 752 meters. This method led to an over performance of about 2.9% with a global satellite depointing of -0.1deg (Fig. 4). After discussion, the FDS team has decided to not update the calibration coefficient and to use the old value for the next OCM. Figure 5 illustrates the realized ground track after orbit maintenance OCM.

			Predicted TOE Mean Param		Observed TOE Mean Param		Observed_Predicted		Predicted Δv		Observed Δv		Efficiency	Δ pointage
		Epoch	sma (km)	i (deg)	sma (km)	i (deg)	sma (km)	i (deg)	ΔVa	ΔVi	ΔVa	ΔVi	%	deg
Initial state		2012/09/16 09:29:42.000	7047,486112600	98,130637132	7047,4861126	98,130637132								
OCM i	Delta	2012/09/18 01:29:10.003	0,2959375	-0,000029194	0,2959375	-0,000029194	0,0000	0,0000	0,1579	-0,0038	0,1579	-0,0038	0,0000	0,0000
Intermediate state		2012/09/18 02:00:00.000	7047,782050100	98,130607938	7047,7820501	98,130607938								
OCM i+1	Delta	2012/09/18 03:49:57.439	0,4320309	-0,000842105	0,4562906	-0,000897797	0,0243	-0,0001	0,2305	-0,1105	0,2434	-0,1178	5,8024	-0,2108
Final state		2012/09/18 08:59:55.999	7048,2140810	98,129765833	7048,2383407	98,129710141								
CM i to i+1	Delta		0,7279684	-0,000871299	0,7522281	-0,000926991	0,0243	-0,0001					2,9012	-0,1054

Figure 4. OCM calibration using graphical method

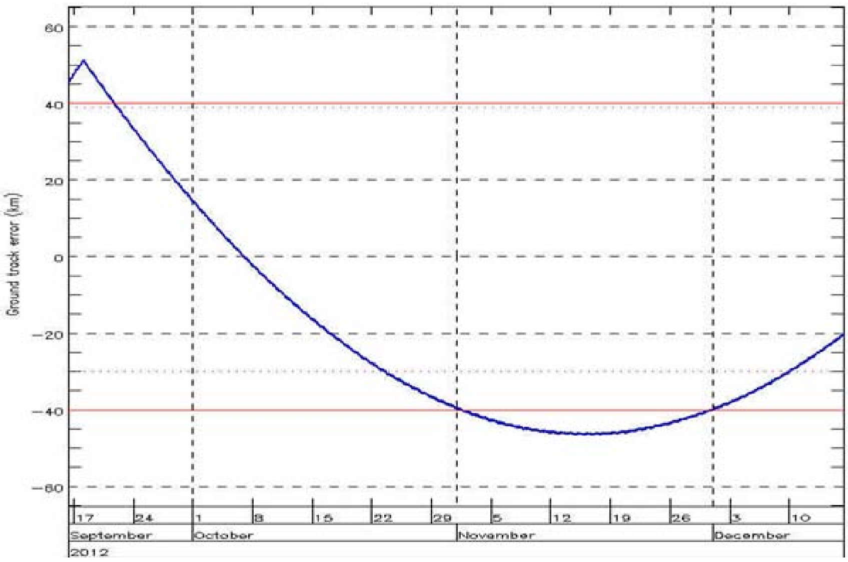

Figure 5. Realized evolution of ground track error after orbit maintenance OCM

Figure 6 illustrates the evolution of the local solar time for the observed period as well as the prediction for the future up to mid of 2016. So, 12 months after the nominal life time of mission. The obtained evolution demonstrates that no correction on inclination will be performed before mid 2017, so, 2 years after the nominal life time of mission. At the end of October 2012, the ground track error at equator and local solar time are respectively -20 km (Ground track error window is +/-40 km) and 22:05:10 (LST window is 21:50±20 mins). The next foreseen OCM should occur in mid January 2013 and is an in-plane maneuver.

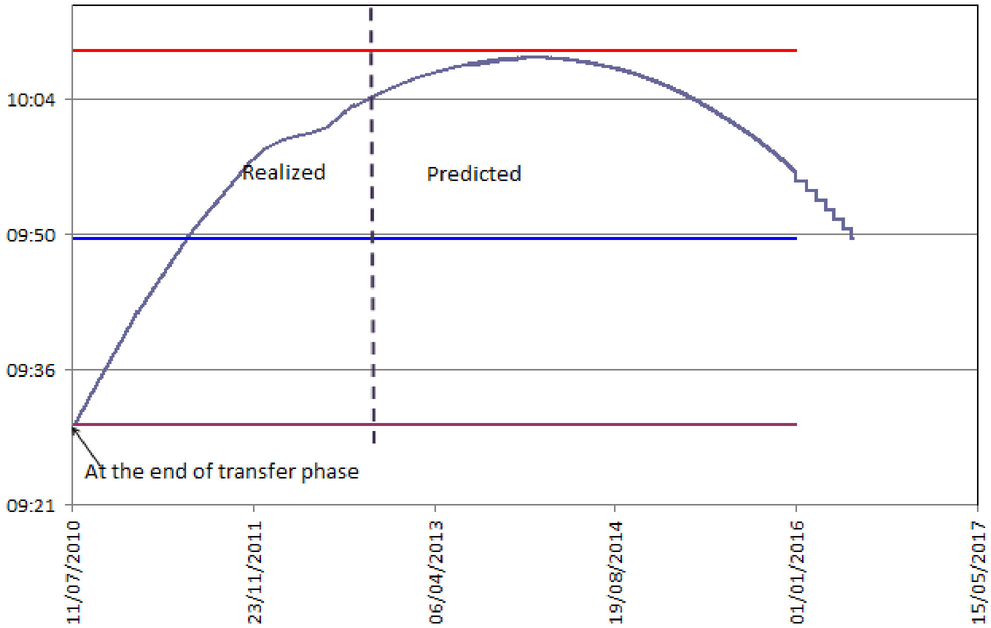

Figure 6. Evolution of Local Solar Time

3. Emergency OCM

3.1 Strategy and Tool used in Analysis

In this section, we describe the first experiences of CDS/ASAL with avoidance maneuvers. Theses emergency activities are considered very critical and are generally supported by or sub contracted to experts in mission analysis domain.

Since September 2010, CDS/ASAL receives from JSpOC collision awareness for ALSAT-2A as soon as the total miss distance is below 1 km or the radial distance is less than 200 meters. Table 2 summarizes all CSM received by CDS/ASAL since the beginning of operational lifetime.

In the absence of any support contract or professional tools, in order to face to this critical situation, an appropriate tool has been developed by the ALSAT-2 team, called CSMAT (Conjunction Summary Message Analysis Tool).

Table 2 Summary of CSM from JsPOC

Number	Primary Object	Secondary Object	TCA	Overall Distance (m)	Radial (m)	In-Track (m)	Cross-track (m)	Alert	Need of Avoidance Maneuver
1	ALSAT-2A	COSMOS 2251 DEB	30/11/2010 09:05:00.000	618	133.00	52.00	602.00	JSpOC's CSM	No
2	ALSAT-2A	COSMOS 970 DEB-14443	05/06/2011 17:16:07.682	507	-85.80	480.70	-138.10	JSpOC's CSM	Yes
	ALSAT-2A	COSMOS 970 DEB-14443	05/06/2011 17:16:07.645	796	-79.90	761.90	-218.30	JSpOC's CSM	Yes
	ALSAT-2A	COSMOS 970 DEB-14443	05/06/2011 17:16:07.711	304	-79.50	282.80	-80.90	JSpOC's CSM	No
3	ALSAT-2A	Known object	28/08/2011 00:38:40.662	682	-185.30	476.60	-451.50	JSpOC's CSM	No
4	ALSAT-2A	Known object	16/11/2011 12:10:32.671	713	-88.30	120.20	697.50	JSpOC's CSM	No
	ALSAT-2A	Known object	16/11/2011 12:10:32.546	938	-96.60	158.90	920.10	JSpOC's CSM	No
5	ALSAT-2A	Known object	21/03/2012 19:21:36.209	747	-133.00	-97.70	729.30	JSpOC's CSM	No
6	ALSAT-2A	COSMOS 2251 DEB-35440	30/03/2012 23:42:43.848	224	148.60	-61.50	-157.30	JSpOC's CSM	No
	ALSAT-2A	COSMOS 2251 DEB-35440	30/03/2012 23:42:43.736	976	124.50	340.20	906.40	JSpOC's CSM	No
7	ALSAT-2A	Known object	12/04/2012 19:07:06.756	316	-189.30	-14.00	253.40	JSpOC's CSM	No
	ALSAT-2A	Known object	12/04/2012 19:07:07.128	555	-179.30	-22.50	525.70	JSpOC's CSM	No
	ALSAT-2A	Known object	12/04/2012 19:07:07.128	641	-304,67	-500,85	259,68	JSpOC's CSM	No
8	ALSAT-2A	COSMOS 2251 DEB-33806	29/04/2012 09:47:28.630	450	-15,4	55,6	-446,3	JSpOC's CSM	Yes
	ALSAT-2A *	COSMOS 2251 DEB-33806	29/04/2012 09:47:28.769	254	-9,6	27,5	-253,2	JSpOC's CSM	Yes
	ALSAT-2A	COSMOS 2251 DEB-33806	29/04/2012 09:47:28.755	287	6,5	35,7	-285,5	JSpOC's CSM	Yes
	ALSAT-2A	COSMOS 2251 DEB-33806	29/04/2012 09:47:28.755	2003	-71,28	-1994,92	-171,95	avoidance Man (+55m on Radial)	
9	ALSAT-2A	COSMOS 2251 DEB-34753	12/05/2012 12:08:32.590	239	-126.90	124.50	-160.60	JSpOC's CSM	No
	ALSAT-2A	COSMOS 2251 DEB-34753	12/05/2012 12:08:32.710	818	-94.40	-485.50	652.50	JSpOC's CSM	No
10	ALSAT-2A	FENGYUN 1C DEB-35151	10/07/2012 02:46:06.642	329	115.00	-166.90	259.40	JSpOC's CSM	No
11	ALSAT-2A	DELTA 1 DEB-28443	13/07/2012 01:26:26.813	195	64.70	-106.10	150.90	JSpOC's CSM	Yes
	ALSAT-2A *	DELTA 1 DEB-28443	13/07/2012 01:26:26.889	97	58.70	-47.80	61.50	JSpOC's CSM	Yes
	ALSAT-2A	DELTA 1 DEB-28443	13/07/2012 01:26:26.911	230	56.30	-130.40	181.70	JSpOC's CSM	Yes
	ALSAT-2A	DELTA 1 DEB-28443	13/07/2012 01:26:26.889	4843	112,68	4820	458	avoidance Man (+21m on Radial)	
12	ALSAT-2A	FENGYUN 1C DEB-36722	01/08/2012 07:49:53.515	205	-62.00	138.40	138.70	JSpOC's CSM	No
13	ALSAT-2A	FENGYUN 1C DEB-31950	14/08/2012 16:31:11.336	463	189.60	63.10	418.10	JSpOC's CSM	No
14	ALSAT-2A	CZ-4 DEB-26141	11/09/2012 12:01:58.133	585	-558	-56	168	JSpOC's CSM	No

* Avoidance maneuver calculated on the second CSM provided by JSpOC at this TCA epoch

The developed tool is designed to retrieve and to process, manually or automatically, the CSM files available in the space-track conjunctions database (www.space-stack.org). It allows also to aid operation team to decide the need of an emergency maneuver. The automatic mode allows to check with a frequency fixed by operator (1, 2, 4 or even 8 hours) the existence of new alerts regarding Algerian satellites (ALSAT-1 and ALSAT-2A). This automatic mode is very interesting during weekend days where a limited team is present at the satellite control centre.

If a new alert about ALSAT-2A is identified, the tool retrieves, treats, and analyzes the corresponding CSM. If the results are positive (no need of avoidance maneuvers), an information message is automatically sent by email to all operations team members. This email summarizes the name of two objects, TCA time, radial, in-track, cross-track, and total miss distances, collision probability and finally the status of the need of an emergency maneuver.

However, if the results are negative (need of an avoidance maneuver), an alert message is automatically sent by email to all operation team. In addition, an SMS is sent automatically to the mobile phone of expert's team. This solution is made to inform the concerning operators to return urgently to the operations centre to face to this critical situation.
Also, CSMAT tool allows to transform the format of the generated orbit ephemeris by the QUARTZ software to the required format and send them by email to JSpOC.

The criteria that used to assess an emergency OCM alert is [3]

If if radial distance < (3*Primary_radial_error) + (3*Secondary_radial_error) + (radius_primary) + (radius_secondary)

Then **Emergency OCM alert**
or
If Collision probability > 0.0001
Then **Emergency OCM alert**

The method used to calculate the collision probability is developed by Patera [4-6].

3.2 First Experiences with Emergency OCM

As discussed in section 1, two avoidance maneuvers were performed due to the space objects close approach to ALSAT-2A on April and July 2012. CDS/ASAL had been informed of theses risks by JSpOC who sent Conjunction Awareness Messages.
On Saturday 28th of April 2012 at 18:00, CSMAT tool checked, retrieved, and analyzed automatically a new conjunction summary message of ALSAT-2A with an identified object "COSMOS 2251 DEB-33806 " on the date 04/29/2012 09:47:28.755. In addition, a conjunction awareness message has been also sent by the Americans JSpOC services.

This first experience is very critical regarding the small radial distance of -9 m between the two objects, and the remaining time (only 3 hours) between the time of treatment of the CSM and the last visibility which can be used to upload the Telecommand plan to ALSAT-2A to perform the avoidance maneuver before conjunction.
These urgent operations required the mobilization of the CDS teams located at Oran and Ouargla cities. A new processing of the CSM file was performed manually using the CSMAT tool to confirm the obtained results. These results showed that at TCA time the secondary object "COSMOS 2251 DEB-33806" was below ALSAT-2A with a radial distance of -9.6 m and a total miss distance of 254 m. Also, the small uncertainty on the position of "COSMOS 2251 DEB-33806" of 14 m on the radial axis (1 sigma) led that the risk of collision is not to negligee and programming an emergency avoidance maneuver became recommended (Fig. 7). At the end of the analysis, a correction of 30.67 m taking into account a 5% over/under

performance is recommended. The date recommended for maneuver is 04/29/2012 07:20:22.769, so 1+1/2 orbit before the TCA time.

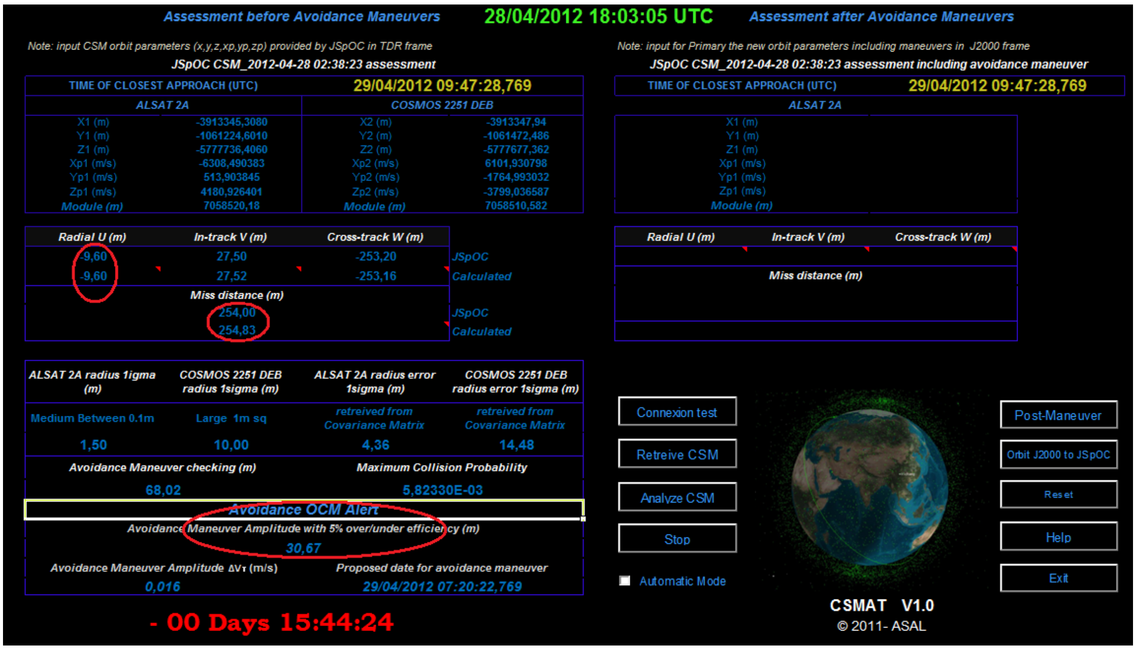

Figure 7. Results of analyzing ALSAT-2A CSM

To show the orbital position at conjunction time and the trajectories of the two objects, the two corresponding orbits were injected into the freeware tracking tool “JSatTrak”. Figure 8 shows the orbital position of the conjunction between ALSAT-2A and "COSMOS 2251 DEB-33806" on the date provided in the CSM (04/29/2012 09:47:28.755).

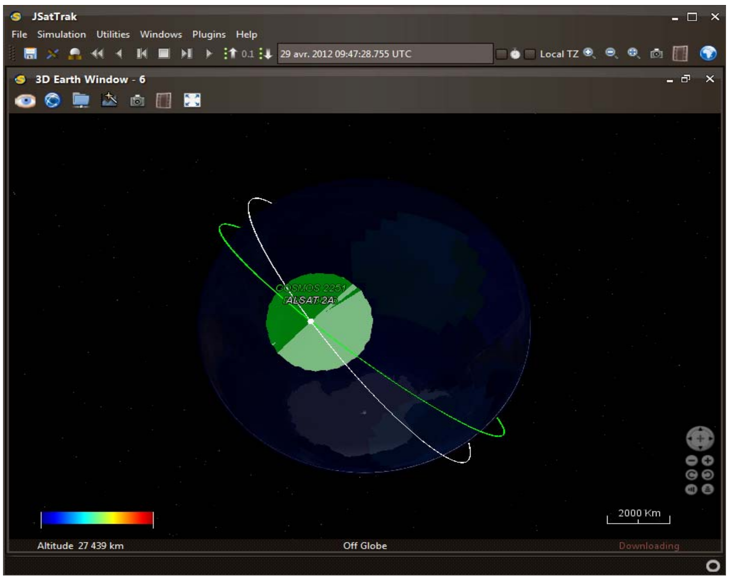

Figure 8. Conjunction between ASLAT-2A and COSMOS2251 DEB-33806 at TCA time

In order to ensure more margins, an avoidance maneuver of 55m on radial axis was implemented and evaluated at the Flight Dynamic System. Then, the resulting orbit was generated as an OPM CCSDS file to verify on the CSMAT tool that the calculated maneuver can minimize the risk of collision. After analysis, the result showed that the initial risk is decreased and the planned maneuver was sufficient (Fig. 9). The collision avoidance maneuver detailed plan is shown in Tab. 3. The generated orbit as an OPM CCSDS taking into account the avoidance maneuver is described in Fig. 10.

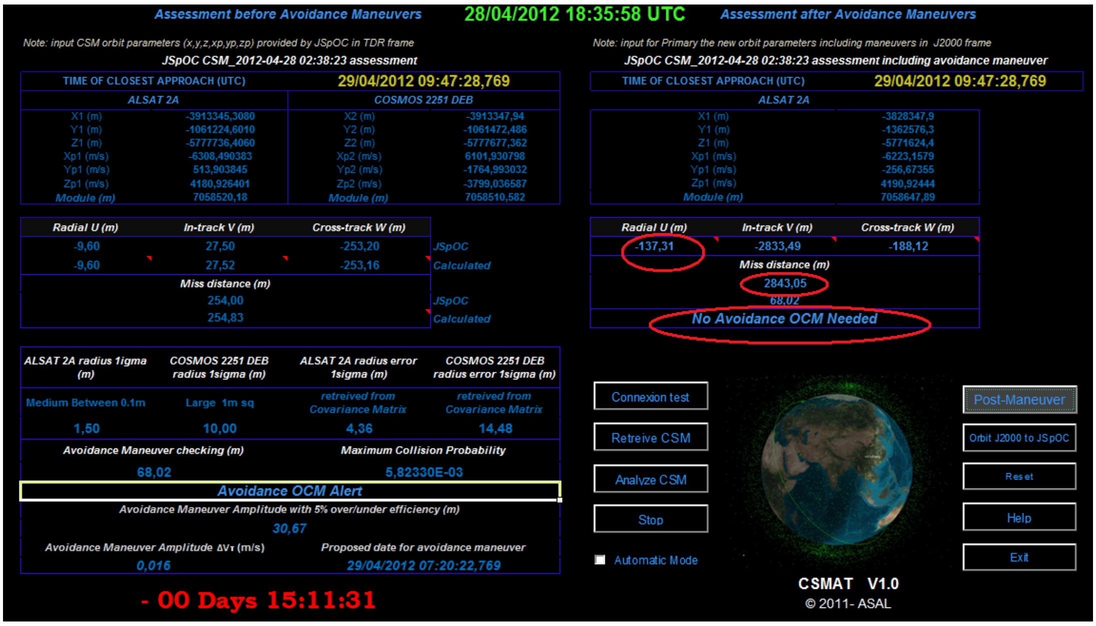

Figure 9. Results of assessment including avoidance maneuver

Table3. Summary of the first emergency maneuver performed on April 2012

	Centroid epoch	ΔV_T (m/s)	ΔV_W (m/s)	Declination (deg)
OCM	2012/04/29 07:20:22.769	0.0308145735	0.0000000000	0.00000

```
CCSDS_OPM_VERS     =  1.0
CREATION_DATE      =  2012-04-29T07:22:17.000
ORIGINATOR         =  QUARTZ

OBJECT_NAME        =  ALSA
OBJECT_ID          =  2009-003A

CENTER_NAME        =  EARTH
REF_FRAME          =  EME2000
TIME_SYSTEM        =  UTC

COMMENT  State Vector
EPOCH              =  29-04-2012T09:47:28.755
X                  =   -3827.5327         [KM]
Y                  =   -1362.5465         [KM]
Z                  =   -5772.1092         [KM]
X_DOT              =      -6.22375588     [KM/S]
Y_DOT              =      -0.25687939     [KM/S]
Z_DOT              =       4.19012044     [KM/S]

COMMENT  Keplerian elements
SEMI_MAJOR_AXIS    =    7044.627181       [KM]
ECCENTRICITY       =       0.002000977
INCLINATION        =      98.133347       [DEG]
RA_OF_ASC_NODE     =     187.880140       [DEG]
ARG_OF_PERICENTER  =     116.627527       [DEG]
TRUE_ANOMALY       =    -172.322680       [DEG]
GM                 =  398600.440000       [KM**3/S**2]

COMMENT  Spacecraft parameters
MASS               =   115.69869          [KG]
SOLAR_RAD_AREA     =     1.20674          [M**2]
SOLAR_RAD_COEFF    =     1.00000
DRAG_AREA          =     0.96098          [M**2]
DRAG_COEFF         =     2.50000
```

Figure 10. Example of OPM CCSDS file used by CSMAT tool

In order to confirm that the proposed maneuver is sufficient to decrease the collision risk and to guarantee that with the new orbit no conjunctions within 3 days, less than 1Km, and less than 200m radial will be identified, the operations team generated orbital ephemeris propagated through the avoidance manoeuvre, and sends them by email to JSpOC for a new assessment. It is required that the orbit ephemeris should be generated in the J2000 Frame, Cartesian representation and recommended with a step of 10 seconds. If the new orbit is considered correct by JSpOC, the operations team proceeds to the generation of the maneuver plan to be uploaded to the satellite. We note that the format of the generated orbit ephemeris by the ALSAT-2 flight dynamics software is different to the required format by JSpOC. The correct format is done by the CSMAT tool. Figures 11 and 12 show the format of generated ephemeris before and after transformation by CSMAT.

```
#  SPACECRAFT ALS2A                : Orbit Ephemeris   Mean of J2000
#
# Period from : 2012/04/28 12:00:00 to : 2012/05/02 12:00:00
#
#
# Epoch (Calendar)    Epoch (MJD)      X          Y           Z           Vx       Vy         Vz       Position    Velocity
#
2012/04/28 12:00:00 56045.50000000 6814.388511 583.708420 -1734.124053 -1.720743 -1.247781 -7.209503 7055.763072  7.516305
2012/04/28 12:00:10 56045.50011574 6796.794127 571.197490 -1806.120178 -1.798041 -1.254339 -7.189344 7055.830715  7.516182
```

Figure 11. Format of orbital ephemeris generated by ALSAT-2 Flight Dynamic System

```
yydddhhmmss.sss       X [KM]        Y [KM]        Z [KM]         X-dot [KM/S]   Y-dot [KM/S]   Z-dot [KM/S]
12119120000.000    6814.388511     583.708420   -1734.124053      -1.720743      -1.247781      -7.209503
12119120010.000    6796.794127     571.197490   -1806.120178      -1.798041      -1.254339      -7.189344
```

Figure 12. Final format of orbital ephemeris for JSpOC transformed by CSMAT Tool

About 2 hours before the TCA epoch, JSpOC service sent to CDS/ASAL an updated conjunction awareness message, and the radial distance between the two objects became more close and positive 6 meters. The treatment of this updated CSM revealed that the planned correction and already uploaded to the satellite remains sufficient (Fig. 13).

During the first contact with the satellite after TCA time, the analysis of telemetry sent by the satellite showed that the avoidance maneuver was well done and the collision risk has been eliminated.

The second emergency maneuver was performed on July 13^{th} 2012. The conjunction concerned ALSAT-2A with a secondary object “DELTA 1 DEB-28433” on the date 13/07/2012 01:26:26.889

The processing of the CSM file using CSMAT tool has demonstrated that at TCA time the secondary object "DELTA 1 DEB-28433" was above ALSAT-2A with a radial distance of 59 m and a total miss distance of 62 m. At the end of the analysis, a correction of 21 m is recommended. The date recommended for maneuver is 2012/07/12 22:59:16.889, so 1+1/2 orbit before the TCA time. The collision avoidance maneuver detailed plan is shown in Tab.

4. The analysis of telemetry sent by the satellite showed that the avoidance maneuver was well done and the collision risk has been eliminated.

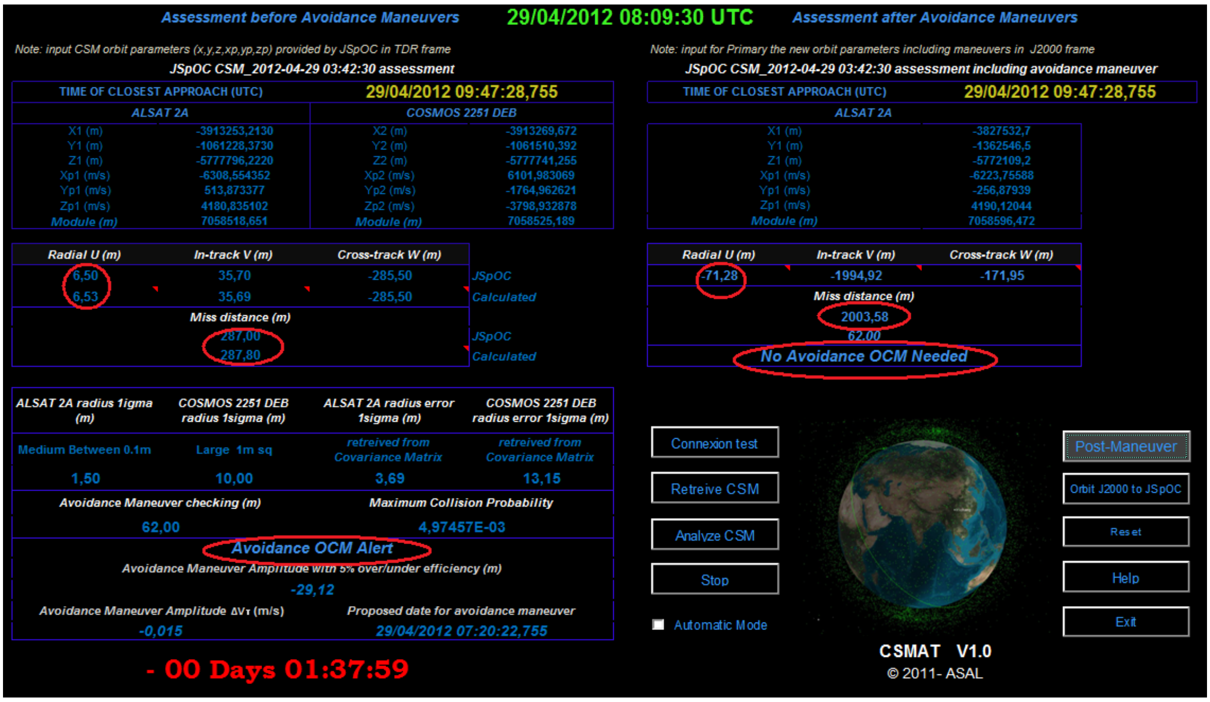

Figure 13. Analysis of the updated CSM

Table4. Summary of the second emergency maneuver performed on July 2012

	Centroid epoch	ΔV_T (m/s)	ΔV_W (m/s)	Declination (deg)
OCM	2012/07/12 22:59:16.889	-0.010056748	0.0000000000	0.00000

4. Conclusion

The whole maintenance Flight Dynamics activities are now handled by CTS/ASAL Flight Dynamics operators. They have already performed 10 regular OCM maneuvers and two emergency OCM maneuvers performed on April and July 2012. The last orbit maintenance has been performed on 18th September 2012 and next one is planned around mid of January 2013.

Since end 2010, CDS/ASAL has received fourteen conjunction alerts regarding ALSAT-2A. A Conjunction Summary Message Analysis Tool has been developed to support operators to retrieve and to analyze the CSM provided by Americans services and to assist them in decision regarding emergency maneuvers. Two experiences with avoidance maneuvers performed respectively, in April and July 2012 have been related.

5. References

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