Microgravity Science and Technology

ISS quasi-steady accelerometric data as a tool for the detection of external disturbances during the period 2009-2016.

--Manuscript Draft--

Manuscript Number:	
Full Title:	ISS quasi-steady accelerometric data as a tool for the detection of external disturbances during the period 2009-2016.
Article Type:	ELGRA2017
Keywords:	Reduced quasi-steady acceleration data; external disturbances detection; International Space Station; ISS disturbances during 2009 and 2016.
Corresponding Author:	Diana Cristina Dubert, PhD Universitat Rovira i Virgili Tarragona, Tarragona SPAIN
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Universitat Rovira i Virgili
Corresponding Author's Secondary Institution:	
First Author:	Marc Marin, PhD
First Author Secondary Information:	
Order of Authors:	Marc Marin, PhD
	Diana Cristina Dubert, PhD
	Maria Jose Simón, Engineer
	Judit Ollé, Chemistry
	Josefa Gavaldà Martínez, Physics
	Xavier Ruiz Martí, Physics
Order of Authors Secondary Information:	
Funding Information:	Ministerio de Economía y Competitividad (ESP2014-53603-P) — Dr. Xavier Ruiz Martí
Abstract:	The present work aims to investigate the degree of correlation existing between the information contained in the ISS reduced quasi-steady accelerometric data and different external mechanical disturbances (reboostings, dockings/undockings, berthings/deberthings and Extra Vehicular Activities), compiled for the period 2009 to 2016. The eight hour mean (Mean8h) and the eight hour root mean square (RMS8h) acceleration values, considered as reduced data, have been extracted from the quasi-steady records provided by NASA Principal Investigator Microgravity Services website. The advantage of applying the present strategy is to drastically reduce the amount of information to be processed all along these eight years. The Mean8h values have been used for the evaluation of trends as function of time while the RMS8h ones were used to define the level (weak, medium and strong) of the different kind of external mechanical disturbances considered. These criteria has been applied for approximately four hundred selected disturbances, compiled in the Annex. Results indicate that reboosting is always detected as a strong disturbance, while dockings/undockings, as weak ones, having lower, though detectable level, depending on the type of spacecraft considered. Extra Vehicular Activities are undetectable by the use of this reduced quasi-steady approach. The inverse problem, in other words, knowing the value of the RMS8h(ai) one could try to predict the kind of disturbance responsible of it, is thus feasible except for berthing/deberthings and Extra Vehicular Activities.

Figure 1

Click here to download line figure Fig.01.tif

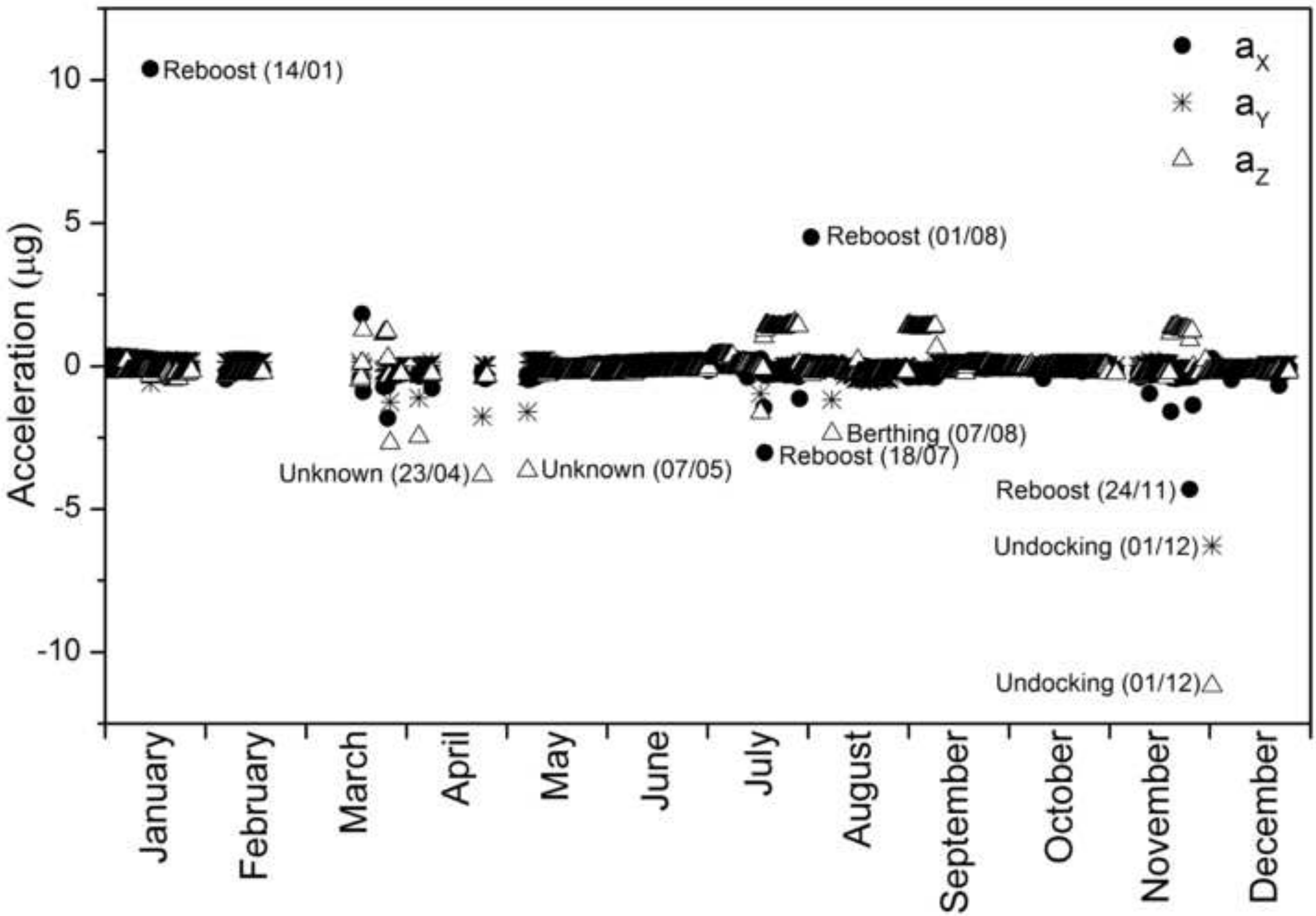

Figure 2

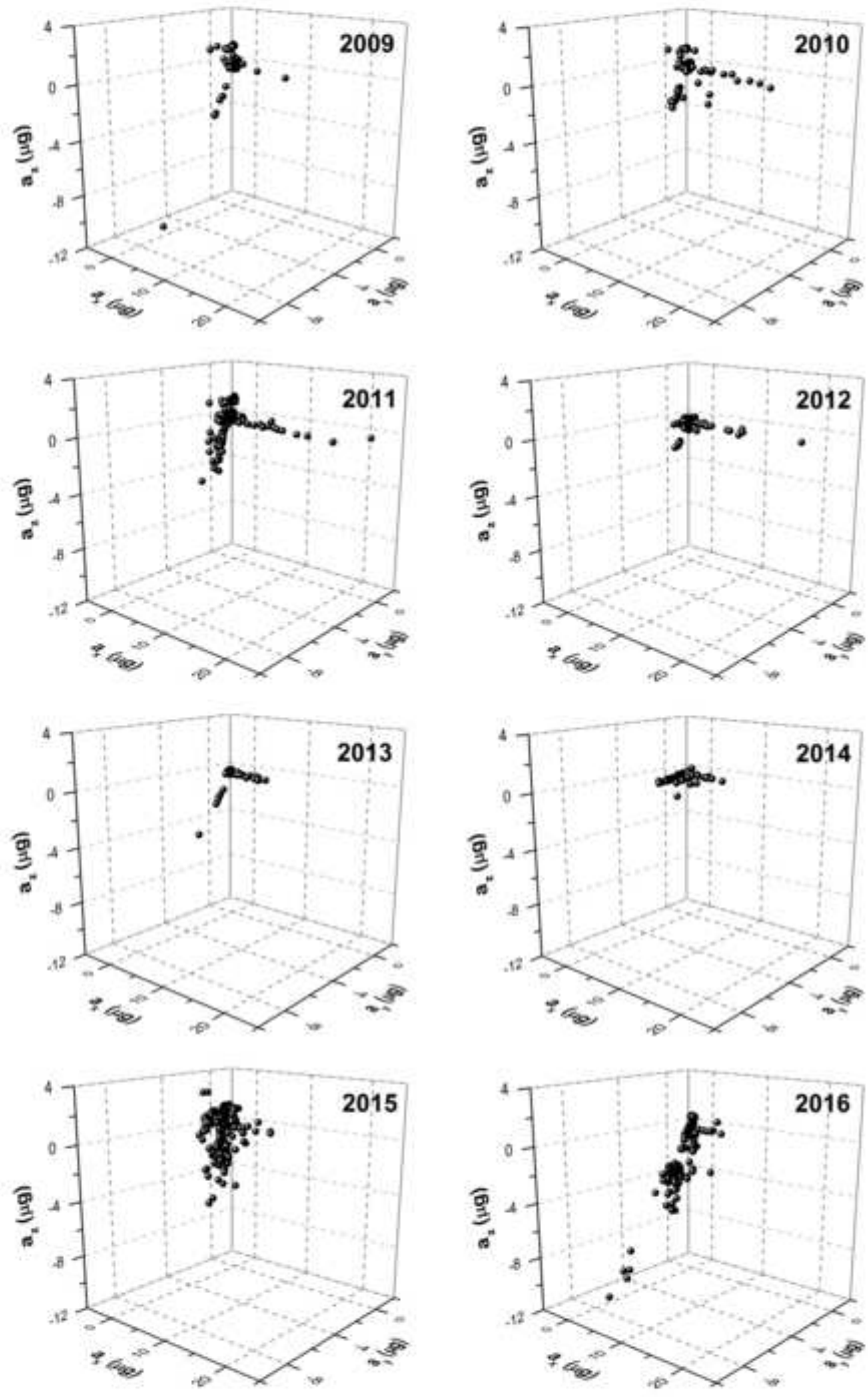

Figure 3

Click here to download line figure Fig.03.tif

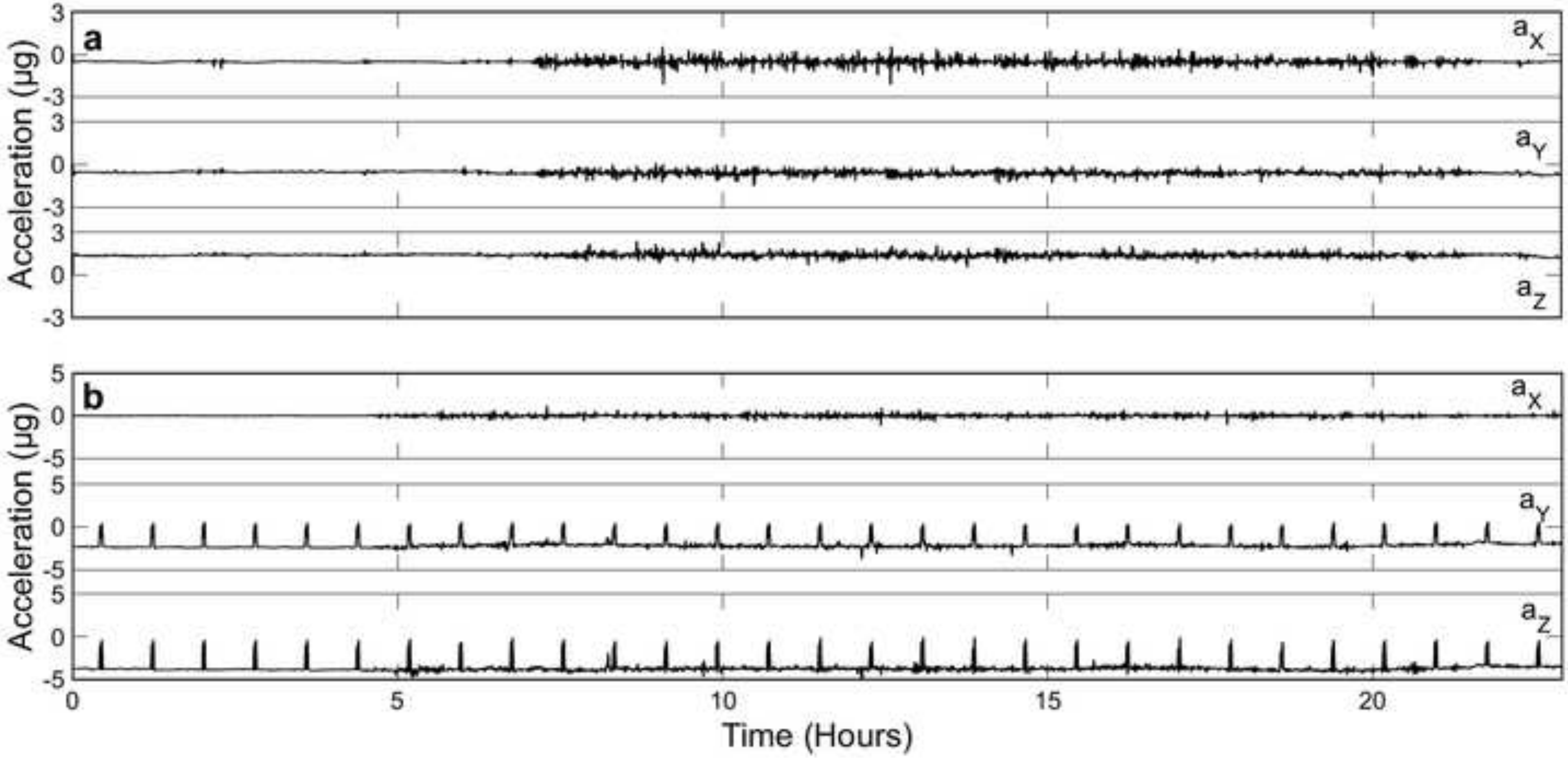

Figure 4 Click here to download line figure Fig.04.tif

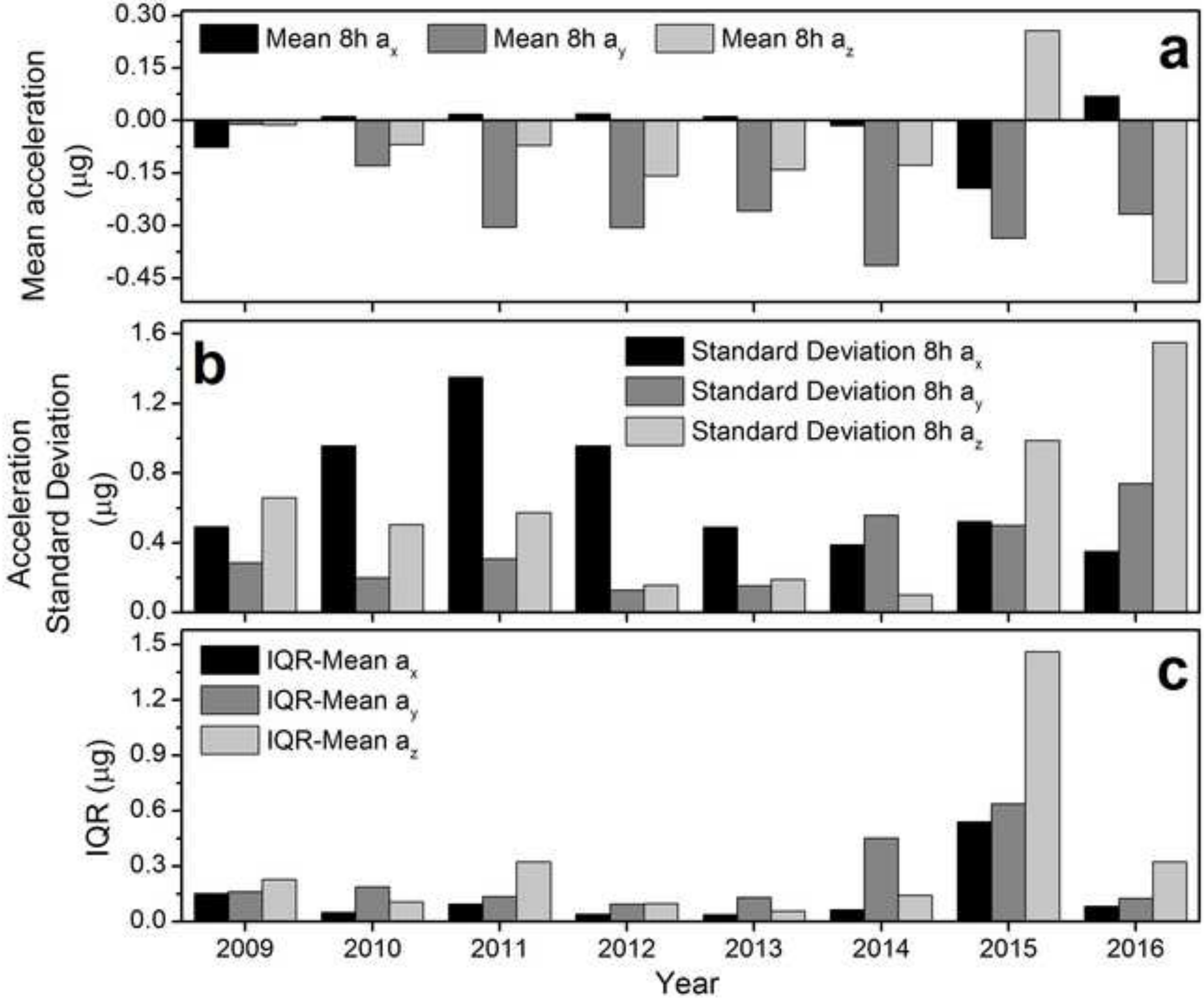

Figure 5

Click here to download line figure Fig.05.tif

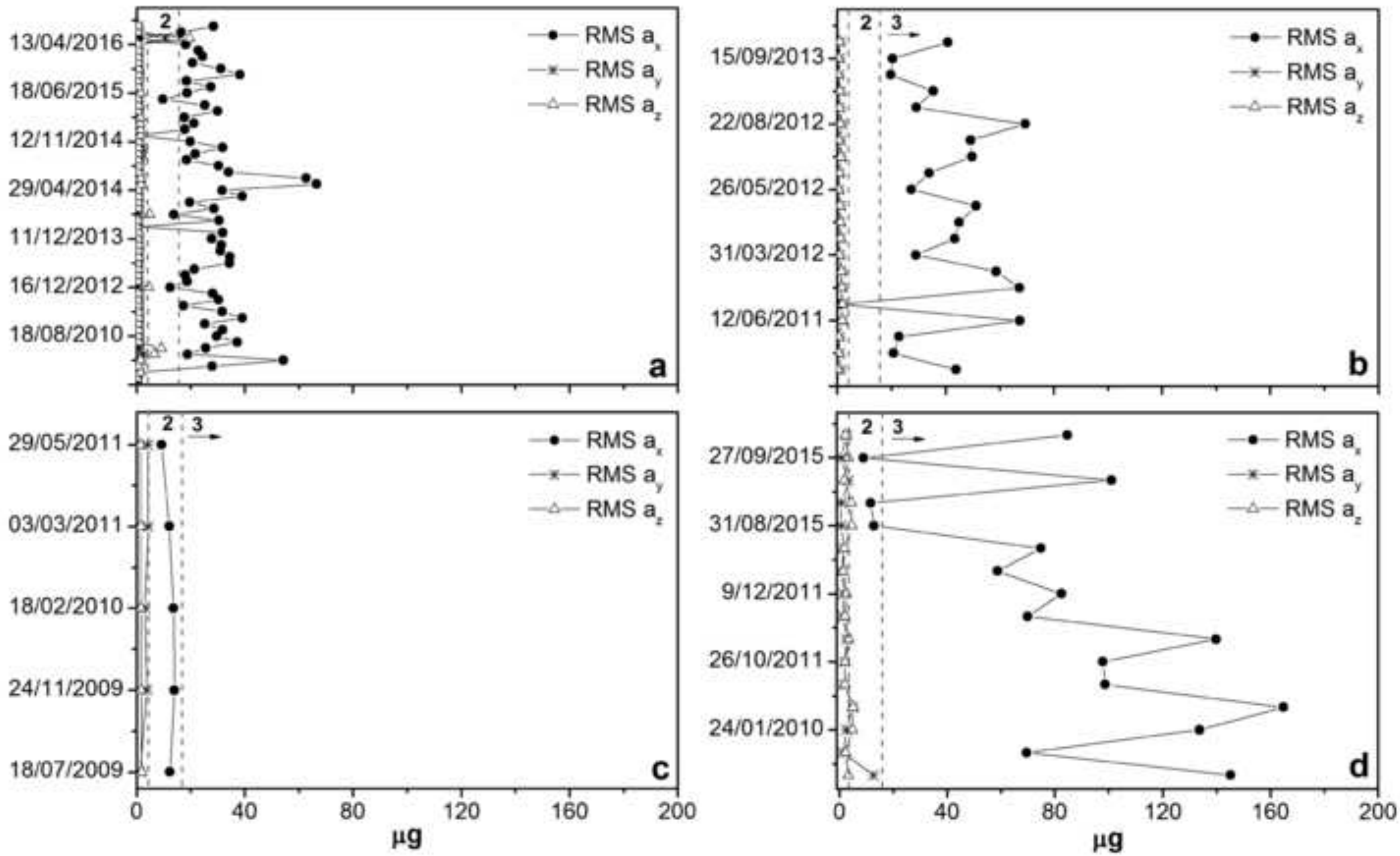

Figure 6

Click here to download line figure Fig.06.tif

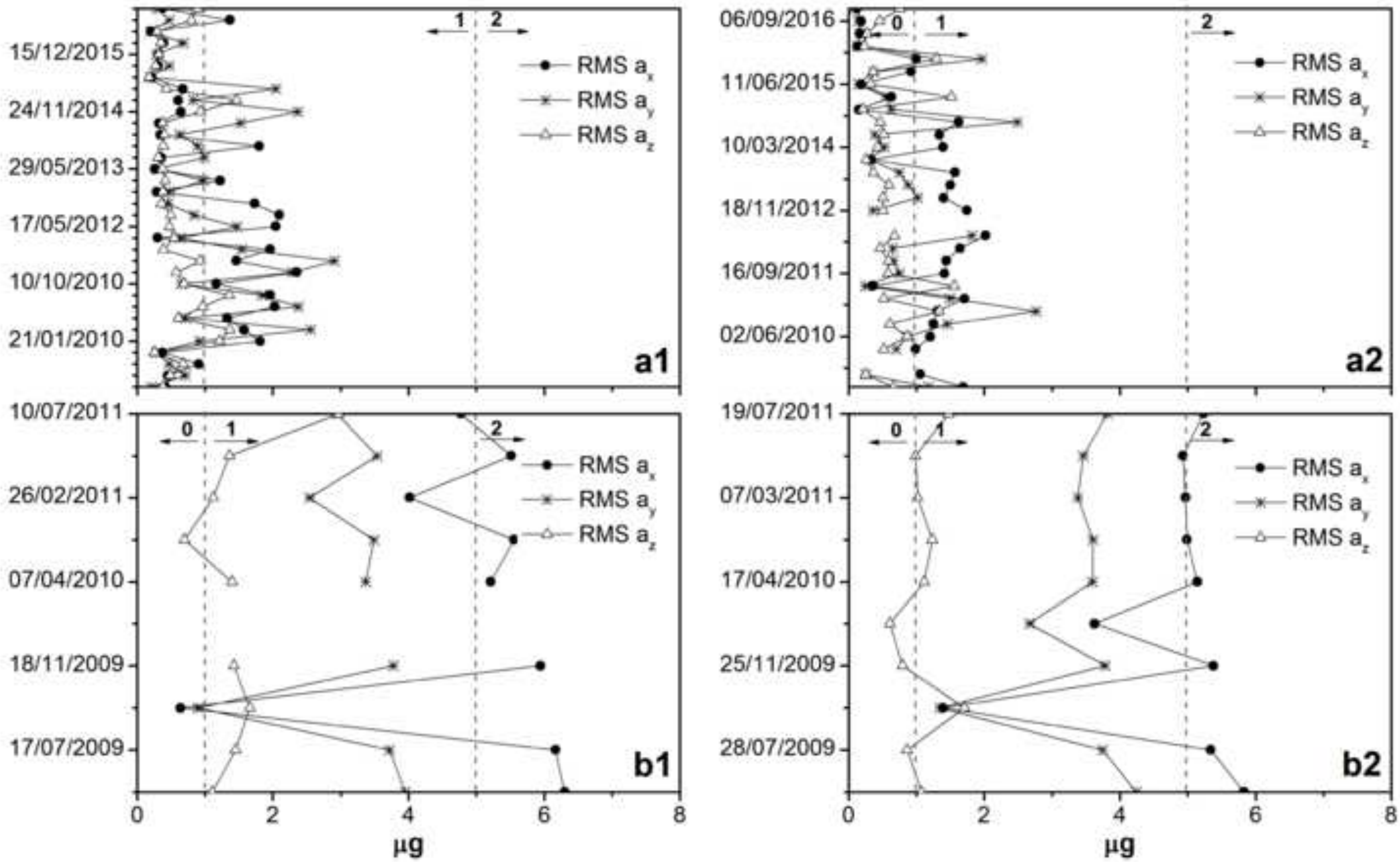

Figure 7

Click here to download line figure Fig.07.tif

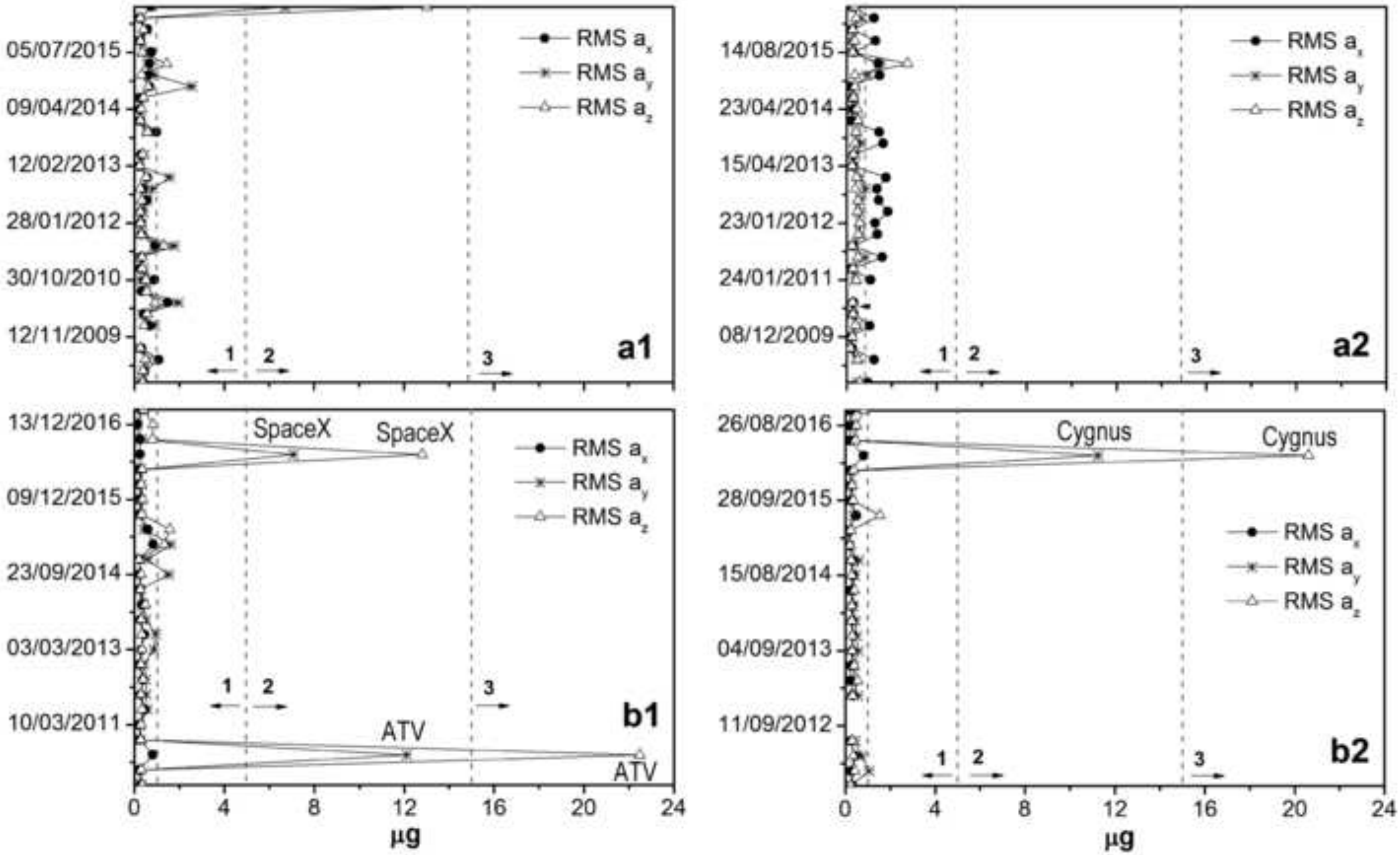

Figure 8

Click here to download line figure Fig.08.tif

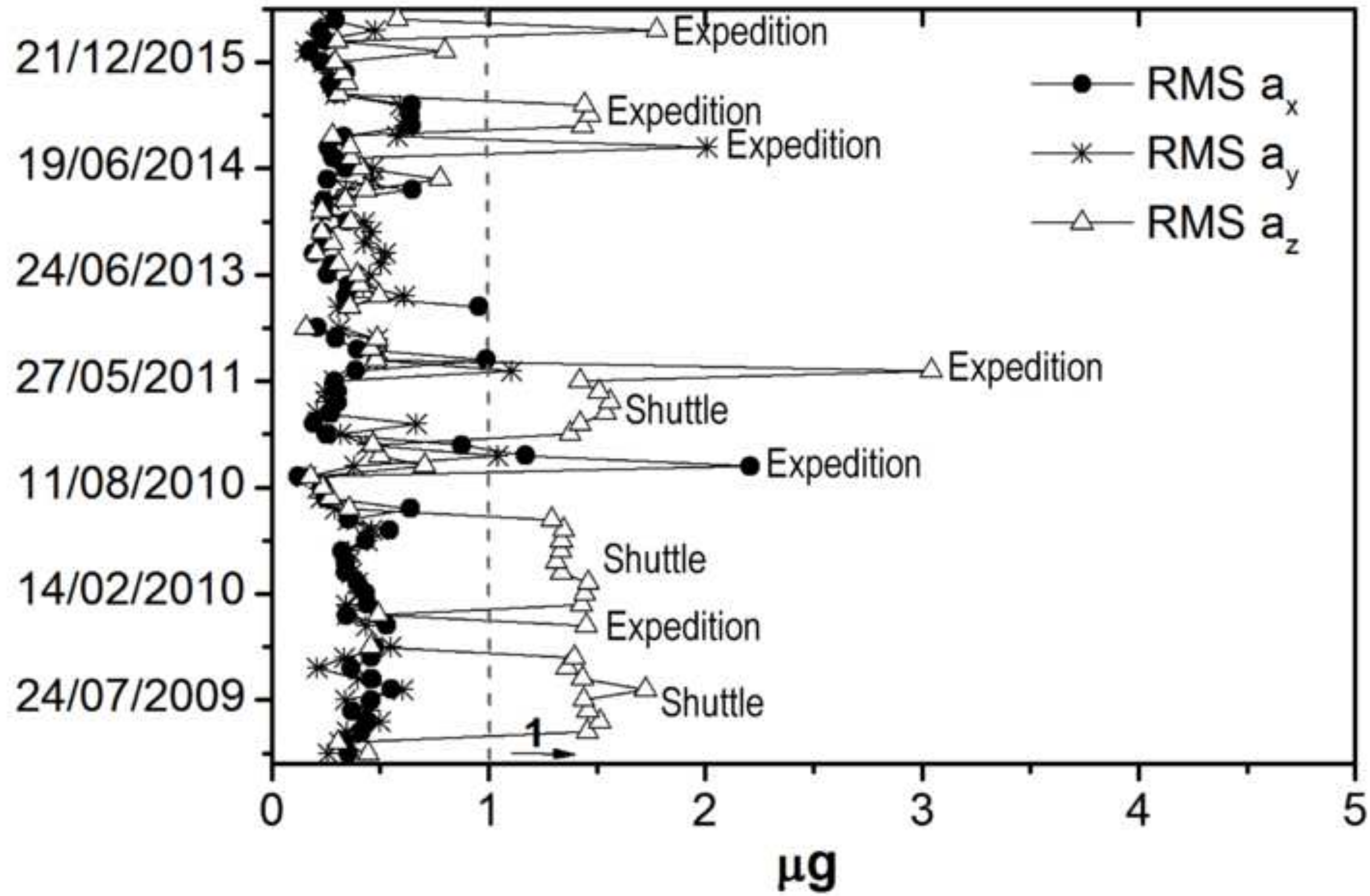

Table 1. Quantitative summary of all disturbances considered to support the present study

	Kind of disturbance																						
	Reboosting					Manned						Unmanned								EVA			Total annual
						Docking			Undocking			Docking/Berthing				Undocking/Deberting							
	Shuttle	Zvezda/Zarya	Progress	ATV	Subtotal	Shuttle	Soyuz	Subtotal	Shuttle	Soyuz	Subtotal	Progress	ATV	grappled (HTV,SpaceX,	Subtotal	Progress	ATV	grappled (HTV,SpaceX,	Subtotal	Shuttle	ISS Expeditions	Subtotal	
2009	2	2	1	-	*5*	4	5	*9*	4	3	*7*	5	-	1	*6*	5	-	1	*6*	14	3	*17*	50
2010	1	3	13	-	*17*	3	7	*10*	3	4	*7*	5	-	-	*5*	4	-	-	*4*	9	6	*15*	58
2011	2	6	4	7	*19*	3	4	*7*	3	4	*7*	4	1	3	*8*	5	1	1	*7*	6	4	*10*	58
2012	-	3	3	11	*17*	-	4	*4*	-	4	*4*	5	1	3	*9*	4	1	3	*8*	-	5	*5*	47
2013	-	-	8	5	*13*	-	4	*4*	-	4	*4*	4	1	3	*8*	4	1	3	*8*	-	11	*11*	48
2014	-	-	15	-	*15*	-	4	*4*	-	4	*4*	5	1	4	*10*	6	-	4	*10*	-	7	*7*	50
2015	-	-	15	-	*15*	-	5	*5*	-	4	*4*	4	-	4	*8*	3	1	3	*7*	-	7	*7*	46
2016	-	1	8	-	*9*	-	4	*4*	-	4	*4*	2	-	4	*6*	3	-	5	*8*	-	4	*4*	35
	5	15	67	23	*110*	10	37	*47*	10	31	*41*	34	4	22	*60*	34	4	20	*58*	29	47	*76*	392

table 2 Click here to download table Table 2.doc

Table 2. – Percentages of the different disturbance levels by using the RMS_{8h} criterion

Spacecraft	Disturbance Type	Reboosting			Manned						Unmanned														
					Docking			Undocking			Docking			Undocking			Berthing			Deberthing			EVA		
		Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za
		%																							
Progress	BkD	9	81	76	-	-	-	-	-	-	94	84	91	50	97	97	-	-	-	-	-	-	-	-	-
	WkD	0	17	19	-	-	-	-	-	-	6	13	6	50	3	3	-	-	-	-	-	-	-	-	-
	MdD	5	2	3	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-	-	-	-	-
	StD	86	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shuttle	BkD	-	-	-	11	11	11	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-	100	96	12
	WkD	-	100	100	-	89	89	50	100	60	-	-	-	-	-	-	-	-	-	-	-	-	-	4	88
	MdD	100	-	-	89	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zvezda	BkD	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WkD	-	69	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MdD	19	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Soyuz	BkD	-	-	-	56	71	88	41	72	86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WkD	-	-	-	44	29	12	59	28	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MdD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ATV	BkD	5	62	62	-	-	-	-	-	-	100	75	75	100	100	100	-	-	-	-	-	-	-	-	-
	WkD	-	38	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MdD	-	-	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	95	-	-	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-
Expedition	BkD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	97	97	90
	WkD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	10
	MdD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Others (HTV, SpaceX Cygnus, Dragon)	BkD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	86	86	100	94	88	-	-	-
	WkD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	10	-	-	6	-	-	-
	MdD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	-	6	-	-	-	-
	StD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-

ISS quasi-steady accelerometric data as a tool for the detection of external disturbances during the period 2009-2016.

M. Marín[a], D. Dubert[b*], M.J. Simón[a], J. Ollé[b], Jna. Gavaldà[b], X. Ruiz[b,c]

[a] Departament d'Enginyeria Mecànica. Universitat Rovira i Virgili, Tarragona. Spain.
[b] Departament Química Física i Inorgànica, Universitat Rovira i Virgili. Tarragona, Spain.
[c] Institut d'Estudis Espacials de Catalunya, IEEC. Barcelona. Spain.
*Corresponding author: dianacristina.dubert@urv.cat

Abstract

The present work aims to investigate the degree of correlation existing between the information contained in the ISS reduced quasi-steady accelerometric data and different external mechanical disturbances (reboostings, dockings/undockings, berthings/deberthings and Extra Vehicular Activities), compiled for the period 2009 to 2016. The eight hour mean ($Mean_{8h}$) and the eight hour root mean square (RMS_{8h}) acceleration values, considered as reduced data, have been extracted from the quasi-steady records provided by NASA Principal Investigator Microgravity Services website. The advantage of applying the present strategy is to drastically reduce the amount of information to be processed all along these eight years. The $Mean_{8h}$ values have been used for the evaluation of trends as function of time while the RMS_{8h} ones were used to define the level (weak, medium and strong) of the different kind of external mechanical disturbances considered. These criteria has been applied for approximately four hundred selected disturbances, compiled in the Annex. Results indicate that reboosting is always detected as a strong disturbance, while dockings/undockings, as weak ones, having lower, though detectable level, depending on the type of spacecraft considered. Extra Vehicular Activities are undetectable by the use of this reduced quasi-steady approach. The inverse problem, in other words, knowing the value of the $RMS_{8h}(a_i)$ one could try to predict the kind of disturbance responsible of it, is thus feasible except for berthing/deberthings and Extra Vehicular Activities.

Keywords: Reduced quasi-steady acceleration data; external disturbances detection; International Space Station; ISS disturbances during 2009 and 2016.

Acknowledgements

We acknowledge the support offered by Dr. K. Hrovat (ZIN Technologies, Inc.). This work was supported by the Spanish Ministerio de Economia y Competitividad, MINECO, grant number ESP2014-53603-P.

1. Introduction

From an accelerometric point of view, spacecrafts and in particular International Space Station (ISS) are extremely complex environments. Non-inertial effects, the interactions with the external medium and the elastic nature of the different materials that make up the station (structural vibrations) are the reasons of this complexity (Penley et al. 2002; Zavalishin et al. 2009; Zavalishin et al. 2013).

As a consequence of the above mentioned characteristics great experimental and/or theoretical efforts have been applied (since the nineties) with the aim of studying the impact of these environments on different experiments (Jules 2004). Fortunately there are experiments insensible to this kind of environment, however many others, such as liquid phase -based experiments, present a high degree of sensibility (Ruiz et al. 2004; Ruiz et al. 2005; Ruiz 2007; Ruiz et al. 2012a; Savino et al. 2002; Tryggvason et al. 2001).

Concerning the ISS environment, the experimental data is recorded by using accelerometers which are located in different modules and are covering the quasi-steady and the vibratory signal regimes, respectively. The quasi-steady regime comprises the lower end of the spectrum (below 0.01 Hz), with magnitudes of the order of micro-g (Kelly 2004a, b; McPherson et al. 2015). The vibrational regime instead, covers frequencies between 0.01 and 250/500 Hz, with magnitudes of the order of mili-g, related with the onboard machinery needed for the crew survival or with the fans and pumps needed for the development of different experiments (Hrovat 2004a, b; McPherson et al. 2015). The amount of information given by these sensors is extremely large, making ~~it~~ very difficult any quick analyses of any relevant episode (in a determined period of time), to be applied.

To overcome these difficulties the present work centres its attention in the quasi-steady part of the spectrum –the most pernicious for the liquid phase experiments (Meseguer 1983; Meseguer et al. 1985; Polezhaev 2004; Ruiz et al. 2010; Ruiz et al. 2012b; Sanz 1985). To do so, the study focuses on the reliability and restrictions of reduced quasi-steady accelerometric data utility. In other words, this consists in reducing the whole day acceleration data to only three values, expressed as mean, $Mean_{8h}$ (a_x, a_y, a_z) and Root Mean Square, RMS_{8h} (a_x, a_y, a_z). Using the above approximation, it has been analyzed acceleration data covering the years between 2009 and 2016, which, as well, includes the last building period of the ISS (2009-2011).

2. Methodology

Quasi-steady acceleration values used herein were recorded by the MAMS (Microgravity Acceleration Measurement System) ossbtmf sensor, always located in U.S. LAB 102 ER1 (Express Rack nr. 1), Lockers 3 and 4 (Destiny module), providing one data each sixteen seconds. The sampling frequency is, thus, 0.0625Hz and the cutoff 0.01 Hz, respectively. Raw data have been trimmean filtered and bias compensated, then plotted daily in the NASA Principal Investigator Microgravity Services, PIMS website and finally grouped in three sets of eight hours each, labeled as 00:00, 08:00 and 16:00 ossbtmf roadmaps, respectively. Based on these three time intervals, the $Mean_{8h}$ and RMS_{8h} values are also consigned in the right side of each plot (PIMS website: PIMS 2018). Notice that, in all cases, the three components of the acceleration are related to the main absolute axes of the Station. In the present analyses both values ($Mean_{8h}$ and RMS_{8h}) have been extracted and used as starting data. In this way were obtained approximately 1100 values per year to attempt further statistical characterization.

Depending on the different $Mean_{8h}$ values, general trends of the Station evolution, all along the period 2009-2016, were evaluated. Remark that, mean values do not offer details of the signal characteristics; on the contrary, they try to summarize them in a single number. Moreover, to characterize the different existing disturbances the RMS_{8h} values were taken into account. These values seemed to be more adequate, compared to the means ones, to be correlated with the shaking episodes associated to different kind of disturbances: reboosting, docking/undocking, berthing/deberthing and Extra Vehicular Activities. To quantify it, different thresholds have been defined which, depending of the magnitude, conveniently establish ~~the kind of~~ strong, medium and weak disturbance. By definition, quantitative values of the above mentioned thresholds are ≥ 15 μg for strong disturbances, 5-15 μg interval for medium disturbances and 1.1-5 μg for low disturbances. Background is reserved for values lower than 1.1μg. Approximately four hundred disturbances, compiled in the Annex, were analyzed and by using these criteria the percentages of each type of disturbance were established. The use of the above strategy enables the possibility to evaluate if this quantitative indicator, associated with the reduced quasi-steady accelerometric data, is adequate to be used in the detection and classification of the specified disturbances. Obviously, the detection by this method does not mean characterization. By construction, this type of indicators are blind to small details.

3. Results

3.1. $Mean_{8h}$ analyses

As an example, Fig. 1 shows the evolution of the $Mean_{8h}$ acceleration components of the quasi-steady values along the year 2009. It can be seen that the acceleration levels are mainly concentrated around zero except some outliers coinciding with disturbances such as reboosting along the X_A direction and docking/undocking in Z_A direction. Notice also that, in this year 2009, the lack of values due to sensor data failures is high, of the order of 24%, though decreased drastically in the following years. This kind of Cartesian representation could be used as standard in the analysis of the different data set, though, Fig. 2 presents a different and more compact tri-dimensional aspect of each of the year studied. Similar distribution in the acceleration data has been detected during the last years of the ISS construction (2009-2011). In other words, a very dense cloud of points around (0,0,0) and some outliers especially in the X_A and Z_A direction associated to the main disturbances (reboostings, dockings/ undockings) occurred during this period (see Annex). During the post-construction period, acceleration values followed the same pattern as before, though with a decrease in the maximum values, except 2015 and 2016 where this behavior changed. In both cases seems that the data was more spread in the Z_A direction compared to the other years. But, analyzing more in details this behavior, it was detected that during a certain time, the sensors seem to record abnormal data distribution along values higher or lower than zero. Figures 3.a and 3.b demonstrate such suspicious situation. There was a period in 2015 when the signal was maintained in positive values especially in Z_A direction and in negative ones for X_A and Y_A directions. Spikes, alternating periodically, especially in Y_A and Z_A directions have also been found by plotting a short time interval of acceleration signal registered during 2016 (see Fig.3 b). This odd behavior changes the distribution pattern found earlier in Fig. 2 during these years, so these values must be considered, at least, carefully.

On the other hand, to have an overview of the data evolution, the acceleration components were averaged for each year and the results plotted in Fig. 4. It was observed an increment of mean acceleration values in the Π_{YZ} plane, more pronounced in Y_A direction, which could be connected to the building of the ISS. Remark once more the strange positive mean value obtained for 2015 and the important increase in the negative mean value for 2016 in the Z_A direction due to possible temporal malfunctioning of the MAMS sensor. Notice also that the standard deviation (σ) on the X_A axis, during the construction period (till 2011), has increased significantly compared to the other two axes. Obviously, during the construction period the shaking on the acceleration records are more intense than in post-construction period. This decrease and subsequent stabilization is also detected during the following years 2012-2016. The interquartile results showed little variability during the years considered, except 2015 when IQR increased.

3.2. RMS_{8h} analyses

Concerning reboostings, the RMS_{8h} values compiled all along the period 2009-2016 are presented in Fig. 5, for Progress (a), Automated Transfer Vehicle (ATV) (b), Space Shuttle (c) and Zvezda/Zarya (d) spacecrafts. Inspecting the RMS values during the reboosting manoeuvres conducted by the different Progress spacecrafts, strong disturbances (StD) have been detected along the X_A axis (see Fig. 5.a.). This is a consequence of the use of the eight attitude control engines when, docked in the aft port of the Zvezda module, produce a gentle variation of the ISS speed in its moving direction X_A (XVV attitude mode operation) (PIMS website: PIMS 2018). At this respect, it is interesting to mention that there are two possible protocols. In the first one, the so-called "4 Progress +X Thrusters", four thrusters are pointed in the X_A direction while that the other four are used for attitude control. In the second protocol, the so-called "8 Progress +X Thrusters”, all thrusters are pointed in the X_A direction, yet, four works on continuous mode and four on pulse on/off mode. In both cases important vibrational responses are generated and very clearly detected as strong on the X_A direction. Unfortunately reduced quasi-steady data cannot identify the protocol used, because RMS_{8h} values are blind against these kind of details. In the other two axes, Y_A and Z_A, the disturbances are weak with some exception during the year 2016, when the disturbances slightly increased in magnitude. Similar behaviour was encountered in case of ATV and Zvezda/Zarya (Figs.5.b and d), therefore, strong disturbances along the X_A axis and very weak for the other two (Y_A and Z_A). In the first case it should be mentioned that, docked in the

Zvezda's aft port, the ATV uses only two of the four main engines pointed, in the –X direction. The orientation control is then usually provided by Zvezda and Progress thrusters. In case of the Zvezda Service Module the two main engines are reserved for orbital manoeuvring, so, for reboostings only 2 from 16 attitude control engines are used. Likewise, the Zarya module has twenty-four large and sixteen small steering jets and two large engines which were used for major orbital changes. But, with the docking of Zvezda in its aft port, these large engines are disabled and only the steering jets are used during reboosting episodes. Concerning Shuttle reboosting results (see Fig.5.c.), the $RMS_{8h}(a_i)$ values indicate a medium level in the X_A direction and a weak one in both Y_A and Z_A directions. These different RMS levels are a consequence of the fact that only the Reaction Control System, RCS, was used for reboostings. This system comprised three groups located in the forward fuselage and in the two independent OMS/RCS pods located each one on both sides of the vertical tail of the aft fuselage. Comparing globally the strength of each of this spacecrafts the Zvezda/Zarya modules showed to have the highest impact, while that the Shuttle had the least. However it must be noted that even with the highest impact the velocity change produced is of the same order (see Annex for quantitative comparisons of Δv) (Sánchez et al. 2015).

Fig. 6 summarizes all the $RMS_{8h}(a_i)$ information corresponding to the different manned missions carried out during the period analyzed here. It has been considered, all dockings/undockings corresponding both to the different Russian Soyuz spacecrafts (from Soyuz TMA-13 up to Soyuz MS-03) (Fig.6a1, 6a2), and to the Space Shuttle missions (from STS-119 up to STS-135) (Fig. 6b1, 6b2). Points in plots Fig. 6.a1, 6.a2 correspond to the different Soyuz missions always docking in the Poisk and Rassvet modules located in the Russian segment of the Station. Poisk is docked to the zenith port of the Zvezda module while that Rassvet is docked to the nadir port of Zarya. The average time during these spacecrafts are attached to the Station, is long, of the order of 160 days. Practically all Soyuz crafts (Baker 2014; Hall et al. 2003) approached the Station moving orthogonally below –nadir port in case of Rassvet - or above – zenith port in case of Poisk- it (R-bar approach mode). The potentially problematic direction of approximation, in terms of the ISS absolute coordinates is, thus, $\pm Z_A$ (perpendicular to the flying direction). Soyuz docks through a typical androgynous system consisting in a probe which is automatically guided by the radio telemetry Kurs system into a cone located in the corresponding ISS port (if the Kurs system fails, the TORU system can manually help in the same task). Then, the ISS port latch closes and the probe retracts to firmly pull the two spacecrafts together. All these procedures lessen the strong vibrations usually generated by sudden contacts and also explain the similarities in weak disturbance for all directions, caught by the sensors during these missions. Note that, the undocking event provoked similar behaviour in terms of disturbances, despite the Station, usually, performs a series of important procedures to complete it, which could introduce extra vibrations. For instance, one hour before the undocking, the Station slowly rotates 90 degrees in a counter clockwise sense around the Y_A axis by the use of a combination of Control Moment Gyroscopes (CMG) and Control Thrusters. At the end of this attitude change the detachment is promoted with the help of a set of springs which separates both crafts. Taking into account the values observed in the Figures 6.a1 and 6.a2 it seems that these procedures do not introduce appreciably changes in the $RMS_{8h}(a_i)$ values.

Figs. 6.b1 and 6.b2 shows the data of the ten Shuttle dockings -four Discovery, three Endeavours and three Atlantis- during the period 2009-2011. This period is shorter than the total one 2009-2016 because the International part of the ISS was completed during May 2011 by the Endeavour's crew. The Shuttle docking port was always the same, the Pressure mating Adapter, PMA-2, currently mounted on the forward port of the Harmony connecting node (or Node 2). The reason of this procedure is that this adapter is the only one that has been outfitted with the Station-to-Shuttle Power Transfer System (SSPTS) hardware which allows the docked Shuttle to make use of the power provided by the Station's solar arrays. In this way, reducing usage of the Shuttle's on-board power-generating fuel cells, Shuttles can stay docked longer to the Station. The method typically used to approach the Space Shuttle to the International Space Station, is called the" V-bar approach". In this case, the Shuttle is positioned orthogonally in front of the Station and then the Station begins to be aligned horizontally along a common velocity vector. This movement is maintained all along the operations even in the last phase when the separation distance between the chaser and the target is less than 10 meters. In terms of the ISS Absolute Coordinates, manoeuvre plane is $\Pi(X_A, Y_A)$ and this fact could reasonably explain the present $RMS_{8h}(a_i)$ results, weak and medium values along the X_A, Y_A directions and only weak along the Z_A one (Shayler 2017a, b).

Fig. 7 compiles all the $RMS_{8h}(a_i)$ information corresponding to the different unmanned missions carried out during the above-mentioned period. By one side (Fig. 7a1, 7a2), all dockings/undockings episodes correspond to the different Russian cargo Progress (from Progress M-01M up to Progress MS-03) and, by the other, the rest of the unmanned cargo crafts from Japan, HTV, and the United States, Dragon, Cygnus and SpaceX, successfully berthed/deberthed by the Space Station Remote Manipulator System, SSRMS, during the same period (Fig. 7b1, 7b2). Remark, we have preferred to add the results of the four docked/undocked ATV European missions to the second case together with HTV and SpaceX Dragon, Cygnus cargo crafts before presenting a different subplot with only four points.

Concerning the Progress missions note that this kind of spacecraft normally docks in the Pirs and Zvezda modules, both located in the Russian segment of the Station (it must be emphasized the exceptional case of the Progress M-MIM2 which uses the zenith port of the Zvezda module). The average time during these cargo crafts are attached to the Station is long, roughly 120 days. In case of the nadir port of the Pirs module the approximation of the Station is orthogonal (R-bar approach mode) meanwhile in case of the aft port of the Zvezda module the approximation is affected by the horizontal aligning of the spacecraft and the Station along a common velocity vector (V-bar approach mode). Due to this, in terms of the absolute coordinate system, the disturbances should be more relevant in the Z_A and X_A directions, respectively. Though, Fig.7a1, for dockings events, this kind of disturbances could be considered, at much, as weak as in our classification, because the docking procedure involves a similar androgynous system as the Soyuz one (see explanation above). This tendency is similar in case of separation (undocking) even in the cases of the Space Station performing re-orientation manoeuvres to achieve the proper attitude to support the undocking.

Points in Figure 7.b1 corresponds to nine successful Dragon missions, six Cygnus and six HTV missions. The time during which all these cargo spacecrafts are attached to the Station is moderate, 27, 45 and 42 days in average, respectively. The ISS berthing in case of

SpaceX Dragon, Cygnus and HTV are similar, but different than the Progress one, because all the above-mentioned cargo spacecrafts are firstly grappled by the Space Station Remote Manipulator System, SSRMS, and then fastened to the same Common Berthing Mechanism, CBM located in the Harmony module (nadir port). In summary, this CBM mechanism is composed of two halves. The first active half supports all systems involved in the capture and closure functions while that the second passive half contains the elements required to complete the closure action as well as the seals enabling a pressurized capability. In terms of the absolute coordinate system the disturbance should be more conflictive in the Z_A direction, although the present results do not support this behaviour. In addition, Fig. 7.b1 has also data corresponding to the four ATV missions. The time during which all these European cargo spacecrafts are attached to the Station is longer than before, 140 days in average. In all cases the docking port is always the aft one in the Zvezda module because, during the docking manoeuvres, the ATV and the Station are positioned in such a way that their respective velocity vectors are aligned (V-bar approach). During the last step of this manoeuver the approximation is commanded by a videometer and a telegoniometer which, located in the ATV spacecraft, constantly calculate its distance and orientation against the ISS (Kitmacher 2006). So, in terms of the absolute coordinate system the disturbance should be more conflictive in the X_A direction, although the results do not support this fact. Notice finally that, in Fig. 7.b1 there are two big sharp spikes: one related to the berthing of the SpaceX Dragon CRS-9 and the other to the ATV-2 cargo craft. First spike could be due to a probable malfunction of the sensor, meanwhile the second spike coincides with an accidental blow during the docking process. There is an extra spike (see Fig. 7b2), related to the deberthing of the Cygnus CRS OA-6, which unfortunately has an unknown source.

Due to the lack of a privileged direction, weak and background $RMS_{8h}(a_i)$ values were observed when EVA events were conducted (see Fig. 8). Until 2011, when the building of ISS finished, these events were carried out by both ISS local and Shuttle coming crews (labelled as Expedition and Shuttle, respectively compiled in the Annex). From 2011 till present, the EVA was always conducted by the different ISS crews (International Space Station User's Guide. ISSUserGuideR2).

A quantitative summary of all disturbances considered in the Annex within the eight years analyzed here, is presented in Table 1. There are ~~counted~~ 110 reboostings, 47 manned dockings and 60 unmanned dockings/berthings, 41 manned undockings, 58 unmanned undocking/deberthings and 76 Extra Vehicular Activities. A total of roughly 400 disturbances, originated from different activities on the ISS, which could have weak, medium or strong influence on the ongoing experiments. Mention here that the small differences between the number of dockings/berthings and undockings/deberthings is a consequence of the fact that a spacecraft may have visited the Station before 2009 or left it after 2016. In both cases, neither docking/berthing nor undocking/deberthing episodes are consigned in the Annex. Based on Table 1, the Table 2 compiles the percentages of the different disturbances classified by using the RMS_{8h} criterion previously established. In this way, considering the results of Progress, Zvezda/Zarya and ATV spacecrafts, more than 80% of the reboostings provoked typical strong disturbances along X_A axis only. The background dominates in the other two Y_A and Z_A directions. In case of manned docking/undocking events medium and weak levels are dominant despite of the values corresponding to the Y_A and Z_A directions are similar to the X_A ones. The noisiest manned vehicle was the Shuttle. On the other side, minimum disturbance levels are detected in all directions for unmanned docking/undockings and berthing/deberthings and for all cargo spacecrafts considered. Finally, EVA events involved 100% background levels for all cases and for all directions.

4. Conclusions

The present work investigates the degree of correlation existing between the quantitative information contained in a reduced approach to the ISS quasi-steady accelerometric data and different external mechanical disturbances acting on the Station (reboostings, dockings/undockings, bethings/deberthings and Extra Vehicular activities). To achieve this goal, the $Mean_{8h}$ and the RMS_{8h} values have been extracted from the quasi-steady data provided by NASA Principal Investigator Microgravity Services website (PIMS). The $Mean_{8h}$ values have been used in the analysis of the global reduced quasi-steady acceleration trend as a function of time. Clear differences have been observed in these mean values during the pre and post construction periods in all directions. The eight hour root mean square values have also been used to characterize the level of the different kind of external mechanical disturbances considered. Different quantitative thresholds have been established and, using these thresholds, the percentages of the different disturbances have been calculated. Results indicate that only reboosting is always detected as a strong disturbance while manned dockings/undockings has a lower, but detectable, level depending also on the type of spacecraft considered. Extra Vehicular Activities are undetectable by the use of this reduced quasi-steady approach. The inverse problem - knowing the value of the $RMS_{8h}(a_i)$ try to predict the kind of disturbance associated - is thus feasible, except in case of unmanned docking/undocking, berthing/deberthings and Extra Vehicular Activities. So, reduced quasi-steady accelerometric data could be used as detector, though only partially.

References

Baker, D.: Soyuz Manual (Owners Workshop Manual), Haynes Publishing (2014)

Hall, R., Shayler, D.: Soyuz. A Universal Spacecraft, Springer Praxis Books/Space Exploration (2003)

Hrovat, K.: Analysis Techniques for Vibratory Data. NASA 7th Annual Microgravity Environment Interpretation Tutorial, MEIT. NASA Glenn Research Center, Ohio Aerospace Institute (2004a)

Hrovat, K.: ISS Measured Vibratory Environment. NASA 7th Annual Microgravity Environment Interpretation Tutorial, MEIT. NASA Glenn Research Center, Ohio Aerospace (2004b)

International Space Station User's Guide. ISSUserGuideR2 (http://www.spaceref.com/iss/ops/ISS.User.Guide.R2.pdf)

Jules, K.: Working in a Reduced-gravity Environment: A Primer. NASA 7th Annual Microgravity Environment Interpretation Tutorial, MEIT. NASA Glenn Research Center, Ohio Aerospace Institute (2004)

Kelly, E.: Analysis Techniques for Quasi-steady Data. NASA 7th Annual Microgravity Environment Interpretation Tutorial, MEIT. NASA Glenn Research Center, Ohio Aerospace Institute (2004a)

Kelly, E.: ISS Measured Quasi-steady Environment. NASA 7th Annual Microgravity Environment Interpretation Tutorial, MEIT. NASA Glenn Research Center, Ohio Aerospace Institute (2004a)

Kitmacher, G.: Reference Guide to the International Space Station. National Aeronautics and Space Administration, Washington, DC (2006), NASA SP-2006-557

McPherson, K., Hrovat, K., Kelly, E., Keller, J.: A researcher's guide to: International Space Station. Acceleration Environment, National Aeronautics and Space Administration (2015)

Meseguer J.: The breaking of axisymmetric slender liquid bridges. J. Fluid Mech. 130, 123-151 (1983)

Meseguer, J., Sanz, A.: Numerical and experimental study of the dynamics of axisymmetric slender liquid bridges. J. Fluid Mech. 153, 83-101 (1985)

Penley, N.J., Schafer, C.P., Bartoe, J.D.F.: The international space station as a microgravity research platform. Acta Astronaut. 50(11), 691-696 (2002), ISSN 0094-5765

http://pims.grc.nasa.gov/html/ISSAccelerationArchive.html, (2018). Accessed 18 January 2018

Polezhaev, V.: The Use of Micro-acceleration Data for Convection Modeling and the Analysis of Convection Limits. NASA 7th Annual Microgravity Environment Interpretation Tutorial, MEIT. NASA Glenn Research Center, Ohio Aerospace Institute (2004)

Ruiz, X., Ermakov, M.: Semiconductor Bridgman growth inside inertial flight mode orbiting systems of low orbital eccentricity and long orbital period. J. Cryst. Growth. 273, 1-18 (2004)

Ruiz, X., Ermakov, M.: G-pulses and semiconductor segregation in µg Bridgman growth. J. Cryst. Growth. 275, e21-e27 (2005)

Ruiz, X.: Modelling of the influence of residual gravity on the segregation in directional solidification under microgravity. J. Cryst. Growth. 303, 262-268 (2007)

Ruiz, X., Pallares, J., Grau, F.X.: On the accuracy of the interdiffusion measurements at low and moderate Rayleigh numbers. Some computational considerations. Int. J. Heat Mass Tran. 53, 3708-3720 (2010)

Ruiz, X., Bitlloch, P., Ramírez-Piscina, L., Casademunt, J.: Impact of stochastic accelerations on dopant segregation in microgravity semiconductor crystal growth. J. Cryst. Growth. 355, 88-100 (2012a)

Ruiz, X., Pallarés, J.: On the accuracy of the diffusion coefficient measurements using different initial shear cell configurations at low and moderate Rayleigh numbers. Int. J. Heat Mass Tran. 55, 6966-6978 (2012b)

Sánchez, O., Ruiz, X., Pujalte, M., Mercader, I., Batiste, O., Gavaldà, Jna.: On the determination of diffusion coefficients in two-component alloys and doped semiconductors. Several implications concerning the International Space Station, J. Heat Mass Tran. 86, 508-518 (2015).

Sanz, A.: The influence of the outer bath in the dynamics of axisymmetric liquid bridges. J. Fluid Mech. 156, 101-140 (1985)

Savino, R., Paterna, D.: Compatibility of the microgravity environment of the international space station with fluid and material science experimentation. Acta Astronaut. 51(1–9), 229-241 (2002), ISSN 0094-5765

Shayler, D.J.: Assembling and Supplying the ISS, The Space Shuttle Fulfills Its Mission, Springer Praxis Books in Space Exploration, Springer Praxis (2017a)

Shayler, D.J.: Linking the Space Shuttle and Space Stations: Early docking Technologies, Springer Praxis Books in Space Exploration, Springer Praxis (2017b)

Tryggvason, B.V., Duval, W.M.B., Smith, R.W., Rezkallah, K.S., Varma, S., Redden, R.F., Herring, R.A.: The vibration environment on the international space station: Its significance to fluid-based experiments. Acta Astronaut. 48 (2–3), 59-70 (2001), ISSN 0094-5765

Zavalishin, D.A., Belyev, M.Yu., Sazonov, V.V.: Estimation of Dynamic Characteristics of the International Space Station from Measurements of Microaccelerations. Cosmic Res+. 47, 173-84 (2009)

Zavalishin, D.A., Belyaev, M.Yu., Sazonov, V.V.: Study of Vibration Microaccelerations Onboard the International Space Station. Cosmic Res+. 51, 261-69 (2013)

Tables

Table 1. Quantitative summary of all disturbances considered to support the present study

	Kind of disturbance																								Total annual
	Reboosting					Manned						Unmanned								EVA			
						Docking			Undocking			Docking/Berthing				Undocking/Deberting							
	Shuttle	Zvezda/Zarya	Progress	ATV	**Subtotal**	Shuttle	Soyuz	**Subtotal**	Shuttle	Soyuz	**Subtotal**	Progress	ATV	SSRMS grappled (HTV,SpaceX,Cygnu)	**Subtotal**	Progress	ATV	SSRMS grappled (HTV,SpaceX,Cygnu)	**Subtotal**	Shuttle	ISS Expeditions	**Subtotal**	
2009	2	2	1	-	*5*	4	5	*9*	4	3	*7*	5	-	1	*6*	5	-	1	*6*	14	3	*17*	50
2010	1	3	13	-	*17*	3	7	*10*	3	4	*7*	5	-	-	*5*	4	-	-	*4*	9	6	*15*	58
2011	2	6	4	7	*19*	3	4	*7*	3	4	*7*	4	1	3	*8*	5	1	1	*7*	6	4	*10*	58
2012	-	3	3	11	*17*	-	4	*4*	-	4	*4*	5	1	3	*9*	4	1	3	*8*	-	5	*5*	47
2013	-	-	8	5	*13*	-	4	*4*	-	4	*4*	4	1	3	*8*	4	1	3	*8*	-	11	*11*	48
2014	-	-	15	-	*15*	-	4	*4*	-	4	*4*	5	1	4	*10*	6	-	4	*10*	-	7	*7*	50
2015	-	-	15	-	*15*	-	5	*5*	-	4	*4*	4	-	4	*8*	3	1	3	*7*	-	7	*7*	46
2016	-	1	8	-	*9*	-	4	*4*	-	4	*4*	2	-	4	*6*	3	-	5	*8*	-	4	*4*	35
	5	15	67	23	*110*	10	37	*47*	10	31	*41*	34	4	22	*60*	34	4	20	*58*	29	47	*76*	**392**

Table 2. – Percentages of the different disturbance levels by using the RMS_{8h} criterion

Spacecraft	Disturbance Type	Reboosting			Manned						Unmanned												EVA		
					Docking			Undocking			Docking			Undocking			Berthing			Deberthing					
		Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za	Xa	Ya	Za
		%																							
Progress	**BkD**	**9**	**81**	**76**	-	-	-	-	-	-	**94**	**84**	**91**	**50**	**97**	**97**	-	-	-	-	-	-	-	-	-
	WkD	**0**	**17**	**19**	-	-	-	-	-	-	**6**	**13**	**6**	**50**	**3**	**3**	-	-	-	-	-	-	-	-	-
	MdD	**5**	**2**	**3**	-	-	-	-	-	-	-	**3**	**3**	-	-	-	-	-	-	-	-	-	-	-	-
	StD	**86**	-	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shuttle	**BkD**	-	-	-	**11**	**11**	**11**	-	-	**40**	-	-	-	-	-	-	-	-	-	-	-	-	**100**	**96**	**12**
	WkD	-	**100**	**100**	-	**89**	**89**	**50**	**100**	**60**	-	-	-	-	-	-	-	-	-	-	-	-	-	**4**	**88**
	MdD	**100**	-	-	**89**	-	-	**50**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zvezda	**BkD**	-	**25**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WkD	-	**69**	**100**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MdD	**19**	**6**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	**81**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Soyuz	**BkD**	-	-	-	**56**	**71**	**88**	**41**	**72**	**86**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WkD	-	-	-	**44**	**29**	**12**	**59**	**28**	**14**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MdD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ATV	**BkD**	**5**	**62**	**62**	-	-	-	-	-	-	**100**	**75**	**75**	**100**	**100**	**100**	-	-	-	-	-	-	-	-	-
	WkD	-	**38**	**38**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MdD	-	-	-	-	-	-	-	-	-	-	**25**	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	**95**	-	-	-	-	-	-	-	-	-	-	**25**	-	-	-	-	-	-	-	-	-	-	-	-
Expedition	**BkD**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**97**	**97**	**90**
	WkD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**3**	**3**	**10**
	MdD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	StD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Others (HTV, SpaceX Cygnus, Dragon)	**BkD**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**100**	**86**	**86**	**100**	**94**	**88**	-	-	-
	WkD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**10**	**10**	-	-	**6**	-	-	-
	MdD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**4**	**4**	-	**6**	-	-	-	-
	StD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**6**	-	-	-

Figure captions

Fig.1 $Mean_{8h}$ evolution of the three components of acceleration during the year 2009

Fig.2 $Mean_{8h}$ acceleration components distribution during the years 2009-2016

Fig.3 One day acceleration signals recorded by MAMS ossbtmf sensor indicating the possible malfunction of the sensor: a) 05/04/2015 and b) 28/07/2016

Fig.4 Yearly $Mean_{8h}$ acceleration components, standard deviation and interquartile ranges during 2009-2016

Fig. 5 $RMS_{8h}(a_i)$ values categorized as weak, medium and strong disturbances corresponding to the reboosting events carried out between 2009-2016 and performed by: a) Progress, b) ATV, c) Shuttle and d) Zvezda/Zarya spacecrafts

Fig.6 $RMS_{8h}(a_i)$ values categorized as weak, medium and strong disturbances corresponding to the manned missions carried out between 2009-2016 and performed by: a1) Soyuz - docking, a2) Soyuz - undocking, b1) Shuttle - docking and b2) Shuttle - undocking

Fig.7 $RMS_{8h}(a_i)$ values categorized as weak, medium and strong disturbances, corresponding to the unmanned missions carried out between 2009-2016 and performed by: a1) Progress - docking, a2) Progress - undocking, b1) others (HTV, SpaceX, Cygnus)- berthing and b2) others - deberthing

Fig.8 $RMS_{8h}(a_i)$ values categorized as weak, medium and strong disturbances to EVA events during 2009-2016

ANNEX

Active disturbances considered in this work all along the period 2009 – 2016.

Note: The quantitative values in the column "Hour" are only indicative due to the fact that disturbances are not instantaneous and the duration depends on their type. Note also that, the characteristic alterations generated in the acceleration components by the different attitude modes (for instance, the periodic variations detected in the a_y, a_z components during the X-axis perpendicular to the Orbital Plane (XPOP) Attitude) have not been considered here. Finally, mention that the quantitative reboosting data are not strictly exact, though they have been included to give the reader an approximate idea of its order of magnitude as well as the associate velocity change.

Acronyms: EVA: Extra Vehicular Activity; STS: Space Transport System; PMA: Pressurized Mating Adapter; SSRMS Space Station Remote Manipulator System (also, Canadarm2 robotic arm); CRS: Commercial Resupply Service;

Year: 2009					
	Day / Month	**Hour (UTC)**	**Disturbance Type**	**Spacecraft / Module**	**Port (Module)**
09/01	14 / 01	18 : 06	Reboosting	Zvezda thrusters (140 s ; |Δv| = 3.1 m/ s)	
09/02	03 / 02	?	Reboosting	Zvezda thrusters (? s ; |Δv| = ? m/ s)	
09/03	06 / 02	04 : 10	Undocking	Progress M-01M (31P)	-
09/04	13 / 02	07 : 18	Docking	Progress M-66 (32P)	Nadir (Pirs)
09/05	10 / 03	16 : 22	EVA	Expedition 18; 4 h 49 m	
09/06	17 / 03	21 : 20	Docking	STS-119 (Discovery)	PMA-2 (Forward, Harmony)
09/07	19 / 03	17 : 16	EVA	Shuttle STS-119; 6 h 27 m	
09/08	21 / 03	16 : 51	EVA	Shuttle STS-119; 6 h 30 m	
09/09	23 / 03	15 : 37	EVA	Shuttle STS-119; 6 h 27 m	
09/10	25 / 03	19 : 53	Undocking	STS-119 (Discovery)	-
09/11	28 / 03	13 : 05	Docking	Soyuz TMA-14 (Altair)	Aft (Zvezda)
09/12	08 / 04	02 : 55	Undocking	Soyuz TMA-13 (Titan)	-
09/13	06 / 05	15 : 18	Undocking	Progress M-66 (32P)	-
09/14	12 / 05	19 : 24	Docking	Progress M-02M (33P)	Nadir (Pirs)
09/15	29 / 05	12 : 34	Docking	Soyuz TMA-15 (Parus)	Nadir (Zarya)
09/16	05 / 06	07 : 52	EVA	Expedition 20; 4 h 54 m	
09/17	10 / 06	06 : 55	EVA	Expedition 20; 0 h 07 m	
09/18	30 / 06	18 : 30	Undocking	Progress M-02M (33P)	-
09/19	02 / 07		Docking *(relocated)*	Soyuz TMA-14 (Altair)	Nadir (Pirs)
09/20	17 / 07	17 : 47	Docking	STS-127 (Endeavour)	PMA-2 (Forward, Harmony)
09/21	18 / 07	00 : 30	Reboosting	Shuttle Endeavour thrusters (900s ; |Δv| = 0.8 m/s)	
09/22		16 : 19	EVA	Shuttle STS-127; 5 h 32 m	
09/23	20 / 07	15 : 27	EVA	Shuttle STS-127; 6 h 53 m	
09/24	22 / 07	14 : 32	EVA	Shuttle STS-127; 5 h 59 m	
09/25	24 / 07	13 : 54	EVA	Shuttle STS-127; 7 h 12 m	
09/26	27 / 07	11 : 33	EVA	Shuttle STS-127; 4h 54 m	
09/27	28 / 07	17 : 26	Undocking	STS-127 (Endeavour)	-
09/28	29 / 07	11 : 12	Docking	Progress M-67 (34P)	Aft (Zvezda)
09/29	01 / 08	08 : 15	Reboosting	Progress M67 thrusters (460 s ; |Δv| = 1.3 m/s)	
09/30	02 / 08	?	Docking	Soyuz TMA-16 (Cepheus)	Aft (Zvezda)
09/31	31 / 08	00 : 54	Docking	STS-128 (Discovery)	PMA-2 (Forward, Harmony)
09/32	01 / 09	21 : 49	EVA	Shuttle STS-128; 6 h 35 m	
09/33	03 / 09	20 : 39	EVA	Shuttle STS-128; 6 h 39 m	
09/34	05 / 09	20 : 39	EVA	Shuttle STS-128; 7 h 01 m	
09/35	08 / 09	19 : 26	Undocking	STS-128 (Discovery)	-
09/36	17 / 09	22 : 27	Berthing	Japanese cargo vehicle HTV1 (Kounotori 1)	Nadir (Node 2, Harmony) *Canadarm2 robotic arm, SSRMS)*
09/37	21 / 09	07 : 25	Undocking	Progress M-67 (34P)	-
09/38	11 / 10	01 : 07	Undocking	Soyuz TMA-14 (Altair)	-
09/39	18 / 10	01 : 40	Docking	Progress M-03M (35P)	Nadir (Pirs)
09/40	30 / 10	15 : 02	Deberthing	Japanese cargo vehicle HTV1 (Kounotori 1)	- *(Canadarm2 robotic arm, SSRMS)*
09/41	12 / 11	15 : 41	Docking	Progress M-MIM2 (containing the Mini-Research Module-2 or, equivalently, Poisk module)	Zenith (Zvezda)
09/42	18 / 11	16 : 51	Docking	STS-129 (Atlantis)	PMA-2 (Forward, Harmony)

09/43	19 / 11	14 : 24	EVA	Shuttle STS-129; 6 h 37 m	
09/44		14 : 31	EVA	Shuttle STS-129; 6 h 8 m	
09/45	23 / 11	13 : 24	EVA	Shuttle STS-129; 5 h 42 m	
09/46	24 / 11	10 : 07	Reboosting	Shuttle Atlantis thrusters (1620s ; |Δv| = 1.14 m/s)	
09/47	25 / 11	09 : 53	Undocking	STS-129 (Atlantis)	-
09/48	01 / 12	03 : 56	Undocking	Soyuz TMA - 15 (Parus)	-
09/49	08 / 12	00 : 16	Undocking	Progress M-MIM2	-
09/50	22 / 12	22 : 48	Docking	Soyuz TMA-17 (Pulsar)	Nadir (Zarya)

Year: 2010					
	Day / Month	**Hour (UTC)**	**Disturbance Type**	**Spacecraft / Module**	**Port (Module)**
10/01	14 / 01	10 : 05	EVA	Expedition 22; 5h 44 m	
10/02	21 / 01	10 : 24	Docking *(relocated)*	Soyuz TMA-16 (Cepheus)	Zenith (Poisk)
10/03	22 / 01	09 : 06	Reboosting	Zvezda thrusters (55 s ; |Δv| = 1 m/s)	
10/04	24 / 01	09 : 01	Reboosting	Zvezda thrusters (155s ; |Δv| = 2.8 m/s)	
10/05	05 / 02	04 : 26	Docking	Progress M-04M (36P)	Aft (Zvezda)
10/06	10 / 02	05 : 06	Docking	STS-130 (Endeavour)	PMA-2 (Forward, Harmony)
10/07	12 / 02	02 : 17	EVA	Shuttle STS-130; 6h 32 m	
10/08	14 / 02	02 : 20	EVA	Shuttle STS-130; 5h 54m	
10/09	17 / 02	02 : 15	EVA	Shuttle STS-130; 5h 48m	
10/10	18 / 02	07 : 31	Reboosting	Shuttle Endeavour thrusters (1860 s ; |Δv| = 1.3 m/s)	
10/11	20 / 02	00 : 54	Undocking	STS - 130 (Endeavour)	-
10/12		21 : 15	Reboosting	Progress M-04M thrusters (1860 s ; |Δv| = 1.3 m/s)	
10/13	18 / 03	08 : 03	Undocking	Soyuz TMA - 16 (Cepheus)	-
10/14	24 / 03	09 : 15	Reboosting	Progress M-04M thrusters (425 s ; |Δv| = 1 m/s)	
10/15	04 / 04	05 : 25	Docking	Soyuz TMA-18 (Cliff)	Zenith (Poisk)
10/16	07 / 04	07 : 44	Docking	STS-131 (Discovery)	PMA-2 (Forward, Harmony)
10/17	09 / 04	05 : 31	EVA	Shuttle STS-131; 6 h 27 m	
10/18	11 / 04	05 : 30	EVA	Shuttle STS-131; 7 h 26 m	
10/19	13 / 04	06 : 14	EVA	Shuttle STS-131; 6 h 24 m	
10/20	17 / 04	12 : 52	Undocking	STS-131 (Discovery)	-
10/21	22 / 04	16 : 30	Undocking	Progress M-03M (35P)	-
10/22	23 / 04	20 : 30	Reboosting	Progress M-04M thrusters (1245 s ; |Δv| = 3 m/s)	
10/23	01 / 05	18 : 30	Docking	Progress M-05M (37P)	Nadir (Pirs)
10/24	10 / 05	11 : 16	Undocking	Progress M-04M (36P)	-
10/25	12 / 05	14 : 23	Docking *(relocated)*	Soyuz TMA-17 (Pulsar)	Aft (Zvezda)
10/26	16 / 05	14 : 28	Docking	STS-132 (Atlantis)	PMA-2 (Forward, Harmony)
10/27	17 / 05	11 : 54	EVA	Shuttle STS-132; 7 h 25 m	
10/28	19 / 05	10 : 38	EVA	Shuttle STS-132; 7 h 9 m	
10/29	21 / 05	10 : 27	EVA	Shuttle STS-132; 6 h 46 m	
10/30	23 / 05	15 : 22	Undocking	STS-132 (Atlantis)	-
10/31	26 /05	06 : 25	Reboosting	Progress M-05M thrusters (590 s ; |Δv| = 0.8 m/s)	
10/32	02 / 06	00 : 04	Undocking	Soyuz TMA-17 (Pulsar)	-
10/33	05 / 06	03 : 20	Reboosting	Zvezda SM thrusters (250 s ; |Δv| = 4.5 m/s)	
10/34	08 / 06	00 : 10	Reboosting	Progress M-05M thrusters (580 s ; |Δv| = 0.8 m/s)	
10/35		01 : 45		Progress M-05M thrusters (465 s ; |Δv| = 0.6 m/s)	
10/36	17 / 06	22 : 21	Docking	Soyuz TMA-19 (Olympus)	Aft (Zvezda)
10/37	28 / 06	21: 13	Docking *(relocated)*	Soyuz TMA-19 (Olympus)	Nadir (Rassvet)
10/38	04 / 07	16 : 17	Docking	Progress M-06M (38P)	Aft (Zvezda)
10/39	16 / 07	07 : 42	Reboosting	Progress M-06M thrusters (1065 s ; |Δv| = 2.1 m/s)	
10/40	27 / 07	04 : 11	EVA	Expedition 24; 6 h 43 m	
10/41	07 / 08	11 : 19	EVA	Expedition 24; 8 h 3 m	
10/42	11 / 08	12 : 27	EVA	Expedition 24; 7 h 26 m	
10/43	16 / 08	10 : 20	EVA	Expedition 24; 7 h 20 m	
10/44	18 / 08	20 : 30	Reboosting	Progress M-06M thrusters (660 s ; |Δv| = 1.3 m/s)	
10/45	31 / 08	11 : 25	Undocking	Progress M-06M (38P)	-
10/46	12 / 09	11 : 58	Docking	Progress M-07M (39P)	Aft (Zvezda)
10/47	15 / 09	09 : 04	Reboosting	Progress M-07M thrusters (530 s ; |Δv| = 1.2 m/s)	
10/48	25 / 09	02 : 02	Undocking	Soyuz TMA-18 (Cliff)	-
10/49	10 / 10	00 : 01	Docking	Soyuz TMA-01M (Ingul)	Zenith (Poisk)
10/50	20 / 10	19 : 41	Reboosting	Progress M-07M thrusters (230 s ; |Δv| = 0.5 m/s)	
10/51	25 / 10	12 : 25	Undocking	Progress M-05M (37P)	-
10/52	26 / 10	10 : 25	Reboosting	Progress M-07M thrusters (180 s ; |Δv| = 0.4 m/s)	
10/53	30 / 10	16 : 36	Docking	Progress M-08M (40P)	Nadir (Pirs)
10/54	15 / 11	14 : 55	EVA	Expedition 25; 6 h 28 m	
10/55	25 / 11	05 : 03	Reboosting	Progress M-07M thrusters (460 s ; |Δv| = 1 m/s)	
10/56	26 / 11	01 : 23	Undocking	Soyuz TMA-19 (Olympus)	-
10/57	17 / 12	20 : 11	Docking	Soyuz TMA-20 (Varagian)	Nadir (Rassvet)

10/58	22 / 12	16 : 28	Reboosting	Progress M-07M thrusters (1270 s ; |∆v| = 2.4 m/s)	

Year: 2011

	Day / Month	Hour (UTC)	Disturbance type	Spacecraft / Module	Port (Module)
11/01	13 / 01	09 : 00	Reboosting	Progress M-07M thrusters (670 s ; |∆v| = 1.4 m/s)	
11/02	21 / 01	14 : 29	EVA	Expedition 26; 5 h 23 m	
11/03	24 / 01	00 : 43	Undocking	Progress M-08M (40P)	-
11/04	27 / 01	14 : 51	Berthing	Japanese cargo vehicle HTV2 *(Kounotori 2)*	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
11/05	30 / 01	02 : 39	Docking	Progress M-09M (41P)	Nadir (Pirs)
11/06	09 / 02	21 : 37	Reboosting	Progress M-07M thrusters (250 s ; |∆v| = 0.5 m/s)	
11/07	16 / 02	11 : 42	EVA	Expedition 26; 4 h 51 m	
11/08	19 / 02	19 : 26	Berthing *(relocated)*	Japanese cargo vehicle HTV2 *(Kounotori 2)*	Zenith (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
11/09	20 / 02	13 : 12	Undocking	Progress M-07M (39P)	
11/10	24 / 02	15 : 59	Docking	Automated Transfer Vehicle ATV-2, "Johannes Kepler"	Aft (Zvezda)
11/11	26 / 02	19 : 14	Docking	STS-133 (Discovery)	PMA-2 (Forward, Harmony)
11/12	28 / 02	15 : 46	EVA	Shuttle STS-133; 6 h 34 m	
11/13	02 / 03	15 : 42	EVA	Shuttle STS-133; 6 h 14 m	
11/14	03 / 03	14 : 03	Reboosting	Shuttle Discovery thrusters (1560 s ; |∆v| = 1 m/s)	
11/15	07 / 03	12 : 00	Undocking	STS 133 mission (Discovery)	-
11/16	10 / 03	16 : 00	Berthing *(relocated)*	Japanese cargo vehicle HTV2 *(Kounotori 2)*	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
11/17	16 / 03	03 : 27	Undocking	Soyuz TMA-01M (Ingul)	-
11/18	18 / 03	06 : 00	Reboosting	ATV-002 thrusters (880 s ; |∆v| = 2.2 m/s)	
11/19	28 / 03	10 : 15	Deberthing	Japanese cargo vehicle HTV2 (Kounotori 2)	- *(Canadarm2 robotic arm, SSRMS)*
11/20	02 / 04	02 : 36	Reboosting	ATV-002 (240 s ; |∆v| = 0.6 m/s)	
11/21	06 / 04	23 : 09	Docking	Soyuz TMA-21 (Tarkhaniy)	Zenith (Poisk)
11/22	22 / 04	13 : 38	Undocking	Progress M-09M (41P)	-
11/23	29 / 04	14 : 28	Docking	Progress M-10M (42P)	Nadir (Pirs)
11/24	05 / 05	11 : 20	Reboosting	ATV-002 thrusters (240 s ; |∆v| = 0.6 m/s)	
11/25	18 / 05	10 : 14	Docking	STS-134 (Endeavour)	PMA-2 (Forward, Harmony)
11/26	20 / 05	07 : 10	EVA	Shuttle STS-134; 6 h 19 m	
11/27	22 / 05	06 : 05	EVA	Shuttle STS-134; 8 h 7 m	
11/28	23 / 05	21 : 35	Undocking	Soyuz TMA-20 (Varagian)	-
11/29	25 / 05	05 : 43	EVA	Shuttle STS-134; 6 h 54 m)	
11/30	27 / 05	04 : 15	EVA	Shuttle STS-134; 7 h 24 m) **ISS complete (International part)**	
11/31	29 / 05	05 : 03	Reboosting	Shuttle Endeavour thrusters (860 s ; |∆v| = 0.6 m/s)	
11/32	30 / 05	03 : 55	Undocking	STS 134 (Endeavour)	-
11/33	09 / 06	21 : 18	Docking	Soyuz TMA-02M (Eridanus)	Nadir (Rassvet)
11/34	12 / 06	14 : 10	Reboosting	ATV-002 thrusters (2300 s ; |∆v| = 5.6 m/s)	
11/35		18 : 15	Reboosting	ATV-002 thrusters (2450 s ; |∆v| = 6.2 m/s)	
11/36	15 / 06	15 : 55	Reboosting	ATV-002 thrusters (2500 s ; |∆v| = 6.2 m/s)	
11/37	17 / 06	16 : 21	Reboosting	ATV-002 thrusters (1700 s ; |∆v| = 4.4 m/s)	
11/38	20 / 06	14 : 46	Undocking	Automated Transfer Vehicle ATV-002, Johannes Kepler	-
11/39	23 / 06	16 : 37	Docking	Progress M-11M (43P)	Aft (Zvezda)
11/40	29 / 06	12 : 15	Reboosting	Progress M-11M thrusters (1985 s ; |∆v| = 2.1 m/s)	
11/41	01 / 07	12 : 11	Reboosting	Progress M-11M thrusters (1770 s ; |∆v| = 1.9 m/s)	
11/42	10 / 07	15 : 07	Docking	STS 135 (Atlantis)	Pressurized Mating Adapter 2, PMA-2 (Forward, Harmony)
11/43	12 / 07	13 : 22	EVA	Expedition 28; 6 h 31 m **Last spacewalk performed while a space shuttle was docked to the station**	
11/44	19 / 07	06 : 28	Undocking	STS 135 (Atlantis)	-
11/45	03 / 08	14 : 51	EVA	Expedition 28; 6 h 22 m	
11/46	23 / 08	09 : 37	Undocking	Progress M-11M (43P)	-
11/47	16 / 09	00 : 38	Undocking	Soyuz TMA-21 (Tarkhaniy)	-
11/48	29 / 09	16 : 44	Reboosting	Zarya thrusters (170 s ; |∆v| = 2.5 m/s)	
11/49	19 / 10	16 : 15	Reboosting	Zvezda thrusters (110 s ; |∆v| = 1.8 m/s)	
11/50	26 / 10	12 : 52	Reboosting	Zvezda thrusters (110 s ; |∆v| = 1.8 m/s)	
11/51	29 / 10	09 : 04	Undocking	Progress M-10M (42P)	-
11/52	02 / 11	11 : 41	Docking	Progress M-13M (45P)	Nadir (Pirs)
11/53	16 / 11	05 : 24	Docking	Soyuz TMA-22 (Astraeus)	Zenith (Poisk)
11/54	18 / 11	04 : 07	Reboosting	Zvezda SM thrusters (215 s ; |∆v| = 3.4 m/s	
11/55	21 / 11	23 : 00	Undocking	Soyuz TMA-02M (Eridanus)	-
11/56	30 / 11	23 : 11	Reboosting	Zvezda SM thrusters (220 s ; |∆v| = 1 m/s)	

11/57	09 / 12	19 : 50	Reboosting	Zvezda SM thrusters (80 s ; |Δv| = 1.3 m/s)	
11/58	23 / 12	15 : 18	Docking	Soyuz TMA-03M (Antares)	Nadir (Rassvet)

Year: 2012

	Day / Month	Hour (UTC)	Disturbance type	Spacecraft / Module	Port (Module)
12/01	13 / 01	16 : 10	Reboosting	Zvezda thrusters (55 s ; |Δv| = 0.8 m/s)	
12/02	23 / 01	22 : 09	Undocking	Progresss M-13M (45P)	-
12/03	28 / 01	00 : 08	Docking	Progress M-14M (46P)	Nadir (Pirs)
12/04		23 : 50	Reboosting	Zvezda SM thrusters (65 s ; |Δv| = 1 m/s)	
12/05	16 / 02	14 : 31	EVA	Expedition 30; 6 h 16 m	
12/06	29 / 02	10 : 12	Reboosting	Zvezda thrusters (75 s ; |Δv| = 1.2 m/s)	
12/07	28 / 03	22 : 31	Docking	Automated Transfer Vehicle ATV3, “Edoardo Amaldi”	Aft (Zvezda)
12/08	31 / 03	21: 54	Reboosting	ATV-003 thrusters (410 s ; |Δv| = 1 m/s)	
12/09	05 / 04	19 : 06	Reboosting	ATV-003 thrusters (895 s ; |Δv| = 2.2 m/s)	
12/10	19 / 04	11 : 03	Undocking	Progress M – 14M (46P)	-
12/11	22 / 04	14 : 04	Docking	Progress M – 15M (47P)	Nadir (Pirs)
12/12	25 / 04	12 : 13	Reboosting	ATV-003 thrusters (970 s ; |Δv| = 2.3 m/s)	
12/13	27 / 04	08 : 18	Undocking	Soyuz TMA-22 (Astraeus)	-
12/14	04 / 05	08 : 37	Reboosting	ATV-003 thrusters (1220 s : |Δv| = 3 m/s)	
12/15	17 / 05	04 : 35	Docking	Soyuz TMA-04M (Altair)	Zenith (Poisk)
12/16	25 / 05	14 : 56	Berthing	SpaceX Dragon	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
12/17	26 / 05	00 : 10	Reboosting	ATV-003 thrusters (380 s ; |Δv| = 0.8 m/s)	
12/18	31 / 05	09 : 49	Deberthing	SpaceX Dragon	-
12/19	20 / 06	13 : 55	Reboosting	ATV-003 thrusters (560 s ; |Δv| = 1.3 m/s)	
12/20	01 / 07	04 : 47	Undocking	Soyuz TMA-03M (Antares)	-
12/21	17 / 07	04 : 51	Docking	Soyuz TMA-05M (Agate)	Nadir (Rassvet)
12/22	18 / 07	03 :16	Reboosting	ATV-003 thrusters (1160 s ; |Δv| = 2.8 m/s)	
12/23	22 / 07	20 : 05	Undocking	Progress M – 15M (47P)	-
12/24	27 / 07	13 : 20	Berthing	Japanese cargo vehicle HTV3 *(Kounotori 3)*	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
12/25	29 / 07	01 : 00	Docking *(relocated)*	Progress M-15M (47P)	Nadir (Pirs)
12/26	30 / 07	22 : 19	Undocking	Progress M-15M (47P)	-
12/27	02 / 08	01 : 18	Docking	Progress M – 16M (48P)	Nadir (Pirs)
12/28	15 / 08	16 : 00	Reboosting	ATV-003 thrusters (1880 s ; |Δv| = 4.4 m/s)	
12/29	20 / 08	15 : 38	EVA	Expedition 32; 5 h 50 m	
12/30	22 / 08	09 : 45	Reboosting	ATV-003 thrusters (385 s ; |Δv| = 0.9 m/s)	
12/31		13 : 17	Reboosting	ATV-003 thrusters (2090 s ; |Δv| = 4.9 m/s)	
12/32	30 / 08	12 : 16	EVA	Expedition 32; 8 h 17 m	
12/33	05 / 09	11 : 06	EVA	Expedition 32; 6 h 28 m	
12/34	11 / 09	12 : 50	Deberthing	Japanese cargo vehicle HTV3 *(Kounotori 3)*	- *(Canadarm2 robotic arm, SSRMS)*
12/35	14 / 09	03 : 05	Reboosting	ATV-003 thrusters (540 s ; |Δv| = 1.3 m/s)	
12/36	16 / 09	23 : 09	Undocking	Soyuz TMA-04M (Altair)	
12/37	28 / 09	21: 44	Undocking	Automated Transfer Vehicle, ATV–3 “Edoardo Amaldi”	-
12/38	10 / 10	10 : 56	Berthing	SpaceX Dragon CRS-1	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
12/39	25 / 10	12 : 29	Docking	Soyuz TMA-06M (Kazbek)	Zenith (Poisk)
12/40	28 / 10	13 : 29	Deberthing	SpaceX Dragon CRS-1	- *(Canadarm2 robotic arm, SSRMS)*
12/41	31 / 10	13 : 33	Docking	Progress M-17M (49P)	Aft (Zvezda)
12/42		23 : 08	Reboosting	Progress M-16M thrusters (405 s ; |Δv| = 0.4 m/s)	
12/43	01 / 11	12 : 29	EVA	Expedition 33; 6 h 38 m	
12/44	18 / 11	22 : 26	Undocking	Soyuz TMA-05M (Agate)	-
12/45	16 / 12	13 : 34	Reboosting	Progress M-16M thrusters (510 s ; |Δv| = 0.5 m/s)	
12/46	21 / 12	14 : 08	Docking	Soyuz TMA-07M (Sail)	Nadir (Rassvet)
12/47	23 / 12	11 : 28	Reboosting	Progress M-16M thrusters (250 s ; |Δv| = 0.5 m/s)	

Year : 2013

	Day / Month	Hour (UTC)	Disturbance type	Spacecraft / Module	Port (Module)
13/01	17 / 01	02 : 15	Reboosting	Progress M-16M thrusters (270 s ; |Δv| = 0.6 m/s)	
13/02	09 / 02	11 : 30	Undocking	Progress M-16M (48P)	-
13/03	12 / 02	20 : 35	Docking	Progress M-18M (50P)	Nadir (Pirs)
13/04	22 / 02	10 : 30	Reboosting	Progress M-17M thrusters (350 s ; |Δv| = 0.8 m/s)	

13/05	03 / 03	11 : 31	Berthing	SpaceX Dragon CRS-2	Nadir (Node2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
13/06	15 / 03	23 : 00	Undocking	Soyuz TMA-06M (Kazbek)	-
13/07	20 / 03	23 : 30	Reboosting	Progress M-17M thrusters (750 s ; $\lvert\Delta v\rvert$ = 1.7 m/s)	
13/08	26 / 03	09 : 10	Deberthing	SpaceX Dragon CRS-2	-
13/09	29 / 03	02 : 28	Docking	Soyuz TMA-08M (Carat)	Zenith (Poisk)
13/10	15 / 04	12 : 02	Undocking	Progress M-17M (49P)	-
13/11	19 / 04	14 : 03	EVA	Expedition 35; 6 h 38 m	
13/12	26 / 04	12 : 25	Docking	Progress M-19M (51P)	Aft (Zvezda)
13/13	28 / 04	10 : 03	Reboosting	Progress M-19M thrusters (770 s ; $\lvert\Delta v\rvert$ = 1.6 m/s)	
13/14	08 / 05	06 : 45	Reboosting	Progress M-19M thrusters (950 s ; $\lvert\Delta v\rvert$ = 1.7 m/s)	
13/15	11 / 05	12 : 44	EVA	Expedition 35; 5 h 30 m	
13/16	13 / 05	22 : 30	Undocking	Soyuz TMA-07M (Sail)	-
13/17	17 / 05	02 : 15	Reboosting	Progress M-19M thrusters (1020 s ; $\lvert\Delta v\rvert$ = 1.8 m/s)	
13/18	29 / 05	02 : 10	Docking	Soyuz TMA-09M (Olympus)	Nadir (Rassvet)
13/19	11 / 06	13 : 58	Undocking	Progress M-19M (51P)	-
13/20	15 / 06	14 : 07	Docking	Automated Transfer Vehicle, ATV-4 “Albert Einstein”	Aft (Zvezda)
13/21	19 / 06	13 : 05	Reboosting	ATV-4 thrusters (430 s ; $\lvert\Delta v\rvert$ = 1 m/s)	
13/22	24 / 06	13 : 32	EVA	Expedition 36; 6 h 34 m	
13/23	09 / 07	12 : 02	EVA	Expedition 36; 6 h 07 m	
13/24	10 / 07	05 : 30	Reboosting	ATV-4 thrusters (640 s ; $\lvert\Delta v\rvert$ = 1.6 m/s)	
13/25	16 / 07	11 : 57	EVA	Expedition 36; 1 h 32 m	
13/26	25 / 07	20 : 43	Undocking	Progress M-18M (50P)	-
13/27	28 / 07	02 : 26	Docking	Progress M-20M (52P)	Nadir (Pirs)
13/28	09 / 08	13 : 22	Berthing	Japanese cargo vehicle HTV4 *(Kounotori 4)*	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
13/29	16 / 08	14 : 36	EVA	Expedition 36; 7 h 29 m	
13/30	22 / 08	11 : 34	EVA	Expedition 36; 5 h 58 m	
13/31	31 / 08	07 : 15	Reboosting	ATV-4 thrusters (260 s ; $\lvert\Delta v\rvert$ = 0.6 m/s)	
13/32	04 / 09	15 : 07	Deberthing	Japanese cargo vehicle HTV4 *(Kounotori 4)*	- *(Canadarm2 robotic arm, SSRMS)*
13/33	10 / 09	23 : 37	Undocking	Soyuz TMA-08M (Carat)	-
13/34	15 / 09	12 : 42	Reboosting	ATV-4 thrusters (210 s ; $\lvert\Delta v\rvert$ = 0.5 m/s)	
13/35	26 / 09	00 : 45	Docking	Soyuz TMA-10M (Pulsar)	Zenith (Poisk)
13/36	29 / 09	11 : 45	Berthing	Cygnus Orb-D1	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
13/37	02 / 10	19 : 22	Reboosting	ATV-4 thrusters (800 s ; $\lvert\Delta v\rvert$ = 1.9 m/s)	
13/38	22 / 10	10 : 45	Deberthing	Cygnus Orb-D1	- *(Canadarm2 robotic arm, SSRMS)*
13/39	28 / 10	08 : 55	Undocking	Automated Transfer Vehicle, ATV-4 “Albert Einstein”	-
13/40	07 / 11	08 : 00	Docking	Soyuz TMA-11M (Vostok)	Nadir (Rassvet)
13/41	09 / 11	14 : 34	EVA	Expedition 37; 5 h 50 m	
13/42	10 / 11	23 : 26	Undocking	Soyuz TMA-09M (Olympus)	-
13/43	29 / 11	22 : 30	Docking	Progress M-21M (53P)	Aft (Zvezda)
13/44	11 / 12	16 : 34	Reboosting	Progress M-21M thrusters (495 s ; $\lvert\Delta v\rvert$ = 1 m/s)	
13/45	13 / 12	14 : 57	Reboosting	Progress M-21M thrusters (620 s ; $\lvert\Delta v\rvert$ = 1.3 m/s)	
13/46	21 / 12	12 : 01	EVA	Expedition 38; 5 h 28 m	
13/47	24 / 12	11 : 53	EVA	Expedition 38; 7 h 30 m	
13/48	27 / 12	13 : 00	EVA	Expedition 38; 8 h 07 m	

Year: 2014					
	Day / Month	**Hour (UTC)**	**Disturbance type**	**Spacecraft / Module**	**Port (Module)**
14/01	12 / 01	10 : 30	Berthing	Cygnus CRS Orb-1	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
14/02	18 / 01	00 : 15	Reboosting	Progress M-21M thrusters (620 s ; $\lvert\Delta v\rvert$ = 1.3 m/s)	
14/03	27 / 01	11 : 30	EVA	Expedition 38; 6 h 08 m	
14/04	03 / 02	16 : 21	Undocking	Progress M-20M (51P)	-
14/05	05 / 02	21 : 22	Docking	Progress M-22M (54P)	Nadir (Pirs)
14/06	18 / 02	11 : 25	Deberthing	Cygnus CRS Orb-1	- *(Canadarm2 robotic arm, SSRMS)*
14/07	10 / 03	23 : 02	Undocking	Soyuz TMA-10M (Pulsar)	-
14/08	13 / 03	04 : 00	Reboosting	Progress M-21M thrusters (530 s ; Δv = 1.2 m/s)	
14/09	17 / 03	01 : 30	Reboosting	Progress M-21M thrusters (480 s ; $\lvert\Delta v\rvert$ = 0.6 m/s)	
14/10	27 / 03	21 : 45	Docking	Soyuz TMA-12M (Cliff)	Zenith (Poisk)
14/11	28 / 03	22 : 40	Reboosting	Progress M-21M thrusters (490 s ; $\lvert\Delta v\rvert$ = 1.1 m/s)	
14/12	03 / 04	20 : 45	Reboosting	Progress M-21M thrusters (260 s ; $\lvert\Delta v\rvert$ = 0.6 m/s)	
14/13	07 / 04	12 : 58	Undocking	Progress M-22M (54P)	-

14/14	09 / 04	21 : 14	Docking	Progress M-23M (54P)	Nadir (Pirs)
14/15	12 / 04	15 : 25	Reboosting	Progress M-23M thrusters (850 s ; |Δv| = 1.9 m/s)	
14/16	20 / 04	11 : 14	Berthing	SpaceX Dragon CRS-3	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
14/17	23 / 04	08 : 58	Undocking	Progress M-21M (53P)	-
14/18		13 : 56	EVA	Expedition 39; 1 h 36 m	
14/19	25 / 04	12 : 13	Docking	Progress M-21M (53P)	Aft (Zvezda)
14/20	29 / 04	07 : 45	Reboosting	Progress M-21M thrusters (610 s ; |Δv| = 1.4 m/s)	
14/21	13 / 05	21 : 36	Undocking	Soyuz TMA-11M (Vostok)	-
14/22	18 / 05	12 : 55	Deberthing	SpaceX Dragon CRS-3	- *(Canadarm2 robotic arm, SSRMS)*
14/23	29 / 05	01 : 44	Docking	Soyuz TMA-13M (Cepheus)	Nadir (Rassvet)
14/24	09 / 06	13 : 29	Undocking	Progress M-21M (53P)	-
14/25	16 / 06	10 : 36 - 12 : 53	Berthing	Cygnus CRS Orb-2	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
14/26	19 / 06	14 : 10	EVA	Expedition 40; 7 h 23 m	
14/27	25 / 06	10 : 30	Reboosting	Progress? (1105 s ; |Δv| = 1.8 m/s)	
14/28	11 / 07	14 : 50	Reboosting	Progress? (90 s ; |Δv| = 1.4 m/s)	
14/29	21 / 07	21 : 44	Undocking	Progress M-23M (55P)	-
14/30	23 / 07	10 : 50	Reboosting	Progress? (80 s, ; |Δv| = 0.6 m/s)	
14/31	24 / 07	03 : 31	Docking	Progress M-24M (56P)	Nadir (Pirs)
14/32	14 / 08	16 : 55	Reboosting	Progress M-24M thrusters (510 s ; |Δv| = 1.2 m/s)	
14/33	15 / 08	09 : 30	Deberthing	Cygnus CRS Orb-2	- *(Canadarm2 robotic arm, SSRMS)*
14/34	27 / 08	08 : 30	Reboosting	Progress M-22M thrusters (230 s ; |Δv| = 0.6 m/s)	
14/35	18 / 08	14 : 02	EVA	Expedition 40; 5 h 11 m	
14/36	10 / 09	23 : 01	Undocking	Soyuz TMA-12M (Cliff)	-
14/37	14 / 09	02 : 10	Reboosting	Progress M-24M thrusters (260 s ; |Δv| = 0.6 m/s)	
14/38	23 / 09	10 : 52	Berthing	SpaceX Dragon CRS-4	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
14/39	26 / 09	02 : 11	Docking	Soyuz TMA-14M (Tarkhaniy)	Zenith (Poisk)
14/40	07 / 10	12 : 30	EVA	Expedition 41; 6 h 13 m	
14/41	08 / 10	09 : 15	Reboosting	Progress M-24M thrusters (570 s ; |Δv| = 1.4 m/s)	
14/42	12 / 10	13 : 30	Docking	Automated Transfer Vehicle, ATV-5 "Georges Lemaître"	Aft (Zvezda)
14/43		12 : 16	EVA	Expedition 41; 6 h 34 m	
14/44	22 / 10	13 : 28	EVA	Expedition 41; 3 h 38 m	
14/45	25 / 10	12 : 02	Deberthing	SpaceX Dragon CRS-4	- *(Canadarm2 robotic arm, SSRMS)*
14/46	27 / 10	04 : 38	Undocking	Progress M-24M (56P)	-
14/47	29 / 10	13 : 08	Docking	Progress M-25M (57P)	Nadir (Pirs)
14/48	10 / 11	00 : 32	Undocking	Soyuz TMA-13M (Cepheus)	-
14/49	12 / 11	12 : 30	Reboosting	Progress? (240 s ; |Δv| = 0.6 m/s)	
14/50	24 / 11	00 : 40	Docking	Soyuz TMA-15M (Astraeus)	Nadir (Rassvet)

Year: 2015

	Day / Month	Hour (UTC)	Disturbance type	Spacecraft / Module	Port (Module)
15/01	12 / 01	10:54	Berthing	SpaceX Dragon CRS-5	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
15/02	10 / 02	17:11	Deberthing	SpaceX Dragon CRS-5	- *(Canadarm2 robotic arm, SSRMS)*
15/03	14 / 02	13:42	Undocking	Automated Transfer Vehicle, ATV-5 "Georges Lemaître"	
15/04	17 / 02	16 : 57	Docking	Progress M-26M (58P)	Aft (Zvezda)
15/05	21 / 02	12 : 45	EVA	Expedition 42; 6 h 41 m	
15/06	25 / 02	11 : 51	EVA	Expedition 42; 6 h 43 m	
15/07	26 / 02	09 : 20	Reboosting	Progress M-26M thrusters (320 s ; |Δv| = 0.7 m/s)	
15/08	01 / 03	11 : 52	EVA	Expedition 42; 5 h 38 m	
15/09	03 / 03	08 : 00	Reboosting	Progress M-26M thrusters (250 s ; |Δv| = 0.6 m/s)	
15/10	11 / 03	22 : 44	Undocking	Soyuz TMA-14M (Tarkhaniy)	-
15/11	18 / 03	23 : 45	Reboosting	Progress M-26M thrusters (310 s ; |Δv| = 0.7 m/s)	
15/12	28 / 03	01 : 33	Docking	Soyuz TMA-16M (Altair)	Zenith (Poisk)
15/13	02 / 04	18 : 30	Reboosting	Progress M-26M thrusters (230 s ; |Δv| = 0.5 m/s)	
15/14	17 / 04	10 : 55	Berthing	SpaceX Dragon CRS-6	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
15/15	25 / 04	06 : 41	Undocking	Progress M-25M (57P)	-
15/16	06 / 05	05 : 20	Reboosting	Progress M-26M thrusters (750 s ; |Δv| = 1.5 m/s)	
15/17	18 / 05	00 : 30	Reboosting	Progress M-26M thrusters (1920 s ; |Δv| = 1.8 m/s)	
15/18	21 / 05	09 : 29	Deberthing	SpaceX Dragon CRS-6	- *(Canadarm2 robotic arm, SSRMS)*

15/19	08 / 06	19 : 50	Reboosting	Progress M-26M thrusters (380 s ; |Δv| = 0.4 m/s)	
15/20	11 / 06	10 : 20	Undocking	Soyuz TMA-15M (Astraeus)	-
15/21	18 / 06	10 : 50	Reboosting	Progress M-26M thrusters (290 s ; |Δv| = 0.6 m/s)	
15/22	05 / 07	07 : 11	Docking	Progress M-28M (60P)	Nadir (Pirs)
15/23	10 / 07	02 : 50	Reboosting	Progress M-26M thrusters (720 s ; |Δv| = 1.4 m/s)	
15/24	23 / 07	00 : 35	Docking	Soyuz TMA-17M (Antares)	Nadir (Rassvet)
15/25	26 / 07	03 : 40	Reboosting	Progress M-26M thrusters (290 s ; |Δv| = 0.6 m/s)	
15/26	10 / 08	14 : 20	EVA	Expedition 44; 5 h 31 m	
15/27	14 / 08	10 : 19	Undocking	Progress M-26M (58P)	-
15/28	24 / 08	14 : 28	Berthing	Japanese cargo vehicle HTV5 *(Kounotori 5)*	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
15/29	28 / 08	?	Docking *(relocated)*	Soyuz TMA-16M (Altair)	Aft (Zvezda)
15/30	31 / 08	07 : 00	Reboosting	Progress? (530 s ; |Δv| = 0.5 m/s)	
15/31	04 / 09	05 : 30	Docking	Soyuz TMA-18M (Eridanus)	Zenith (Poisk)
15/32	07 / 09	04 : 20	Reboosting	Progress? (530 s ; |Δv| = 0.5 m/s)	
15/33	11 / 09	23 : 39	Undocking	Soyuz TMA-16M (Altair)	-
15/34	14 / 09	01 : 20	Reboosting	Progress? (80 s ; |Δv| = 0.1 m/s)	
15/35	27 / 09	09 : 00	Reboosting	Progress? (370 s ; |Δv| = 0.3 m/s)	
15/36	28 / 09	12 : 12	Deberthing	Japanese cargo vehicle HTV5 *(Kounotori 5)*	- *(Canadarm2 robotic arm, SSRMS)*
15/37	01 / 10	22 : 52	Docking	Progress M-29M (61P)	Aft (Zvezda)
15/38	28 / 10	12 : 03	EVA	Expedition 45; 7 h 16 m	
15/39	06 / 11	11 : 22	EVA	Expedition 45; 7 h 48 m	
15/40	25 / 11	19 : 30	Reboosting	Progress M-29M (61P) (970 s ; |Δv| = 2.1 m/s	
15/41	09 / 12	09 : 10 - 13 : 00	Berthing	Cygnus CRS OA-4	Nadir (Node 1, Unity) *(Canadarm2 robotic arm, SSRMS)*
15/42	11 / 12	09 : 00	Undocking	Soyuz TMA-17M (Antares)	-
15/43	15 / 12	17 : 04	Docking	Soyuz TMA-19M (Agat)	Nadir (Rassvet)
15/44	19 / 12	07 : 35	Undocking	Progress M-28M (60P)	-
15/45	21 / 12	13 : 45	EVA	Expedition 46; 3 h 16 m	
15/46	23 / 12	10 : 27	Docking	Progress MS-01 (62P)	Nadir (Pirs)

Year: 2016					
	Day / Month	**Hour (UTC)**	**Disturbance type**	**Spacecraft / Module**	**Port (Module)**
16/01	11 / 01	02 : 00	Reboosting	Progress M-29M (61P) (1100 s ; |Δv| = 1.8 m/s)	
16/02	15 / 01	12 : 48	EVA	Expedition 46; 4 h 43 m	
16/03	27 / 01	19 : 40	Reboosting	Progress M-29M (61P) (420 s ; |Δv| = 0.8 m/s)	
16/04	03 / 02	12 : 55	EVA	Expedition 46; 4 h 45 m	
16/05	17 / 02	10 : 45	Reboosting	Progress M-29M (61P) (750 s ; |Δv| = 1.2 m/s)	
16/06	19 / 02	10 : 38	Deberthing	Cygnus CRS OA-4	- *(Canadarm2 robotic arm, SSRMS)*
16/07	02 / 03	01 : 03	Undocking	Soyuz TMA-18M (Eridanus)	-
16/08	05 / 03	04 : 15	Reboosting	Progress M-29M (61P) (590 s ; |Δv| = 1.1 m/s)	
16/09	19 / 03	03 : 10	Docking	Soyuz TMA-20M (Burlak)	Zenith (Poisk)
16/10	26 / 03	10 : 51	Berthing	Cygnus CRS OA-6	Nadir (Node 1, Unity) *(Canadarm2 robotic arm, SSRMS)*
16/11	30 / 03	14 : 14	Undocking	Progress M-29M (61P)	-
16/12	02 / 04	17 : 58	Docking	Progress MS-02 (63P)	Aft (Zvezda)
16/13	10 / 04	11 : 23	Berthing	SpaceX Dragon CRS-8	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
16/14	13 / 04	12 : 25	Reboosting	Progress MS-02 (63P) (350 s ; |Δv| = 0.7 m/s)	
16/15	11 / 05	13 : 19	Deberthing	SpaceX Dragon CRS-8	- *(Canadarm2 robotic arm, SSRMS)*
16/16	08 / 06	14 : 00	Reboosting	Progress MS-02 (63P) (320 s ; |Δv| = 0.6 m/s)	
16/17	14 / 06	13 : 30	Deberthing	Cygnus CRS OA-6	- *(Canadarm2 robotic arm, SSRMS)*
16/18	18 / 06	05 : 52	Undocking	Soyuz TMA-19M (Agat)	-
16/19	03 / 07	01 : 48	Undocking	Progress MS-01 (62P)	-
16/20	09 / 07	04 : 07	Docking	Soyuz MS-01 (Irkut)	Nadir (Rassvet)
16/21	19 / 07	00 : 20	Docking	Progress MS-03 (64P)	Nadir (Pirs)
16/22	20 / 07	10 : 56	Berthing	SpaceX Dragon CRS-9	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*
16/23	19 / 08	13 : 04	EVA	Expedition 48; 5 h 58 m	
16/24	25 / 08 - 26 / 08	21: 00 - 10 : 11	Deberthing	SpaceX Dragon CRS-9	- *(Canadarm2 robotic arm, SSRMS)*
16/25	01 / 09	11 : 53	EVA	Expedition 48; 6 h 48 m	
16/26	06 / 09	21 : 51	Undocking	Soyuz TMA-20M (Burlak)	-
16/27	10 / 09	00 : 45	Reboosting	Progress MS-02 (63P) (690 s ; |Δv| = 1.3 m/s)	

16/28	14 / 10	09 : 37	Undocking	Progress MS-02 (63P)	-
16/29	21 / 10	07 : 43	Docking	Soyuz MS-02 (Favor)	Zenith (Poisk)
16/30	23 / 10	09 : 30	Berthing	Cygnus CRS OA-5	Nadir (Node 1, Unity) *(Canadarm2 robotic arm, SSRMS)*
16/31	30 / 10	00 : 35	Undocking	Soyuz MS-01 (Irkut)	-
16/32	02 / 11	02 : 40	Reboosting	Zvezda/Zarya? (140 s ; $\lvert \Delta v \rvert = 2.3$ m/s)	
16/33	19 / 11	20 : 59	Docking	Soyuz MS-03 (Kazbek)	Nadir (Rassvet)
16/34	22 / 11	12 : 45	Deberthing	Cygnus CRS OA-5	- *(Canadarm2 robotic arm, SSRMS)*
16/35	13 / 12	12 : 00	Berthing	Japanese cargo vehicle HTV6 *(Kounotori 6)*	Nadir (Node 2, Harmony) *(Canadarm2 robotic arm, SSRMS)*