X. Decay Epoch of the "Tiangong-1" Spacecraft. February 20, 2018

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The materials presented below represent a continuation of the text under the same name, posted on the “satmotion.ru” website from November 2017 to February 2018 [1–9].

1. The results for February 20, 2018

For 23 preceding time instants of attribution of measurements, the SC orbital parameters were updated over the array of initial measurements, which were presented by the well-known TLEs [10]. The results of the most recent updating (for ID 10) are presented below. Here the coordinates (in km) and velocities (in km/sec) are presented in the Topocentric Equatorial Coordinate System (as in TLEs).

21964.422317- is the modified Julian date = February 19 10^h 8^m 8.18^s
-1432.337720 - x
6475.705653 - y
0.486076 - z
-5.5576023573 - Vx
-1.2476339845 - Vy
5.2695192221 - Vz
0.00344 - Sb (ballistic coefficient, m^2/kg).

Figure 1 presents the ballistic coefficient estimates, the values of the geomagnetic disturbance index (Kp) and the minimized criterion for all preceding time instants of orbital parameters updating after February 10, 2018.

The estimates of ballistic coefficient (Sb) have changed within the range from 0.00260 to 0.00344 m^2/kg, i.e. 1.3 times. The highest drag variations have been observed after February 19 that is the consequence of strong and prolonged geomagnetic storms 15-19 February. The black line marks the Sb estimates averaged over some preceding time interval (the sliding average). On the time interval after January 30 these estimates decreased by 5 %.

The values of a minimized criterion, presented in the figure, have a meaning of the ratio of residuals to the calculated RMS of errors, averaged over the time interval of measurements. These values depend on the magnitude of current residuals and vary from 0.41 to 1.21. Under perfect tuning of algorithm parameters, their average value should be close to 1. The average value of the criterion (0.77) was low enough.

The last smoothed ballistic coefficient value (0.00286 m^2/kg) was used as a constant value in the prediction of SC motion until its entering the dense layers of

the atmosphere. The relevant prediction results for the aforementioned initial data (ID 10) are shown in figure 2.

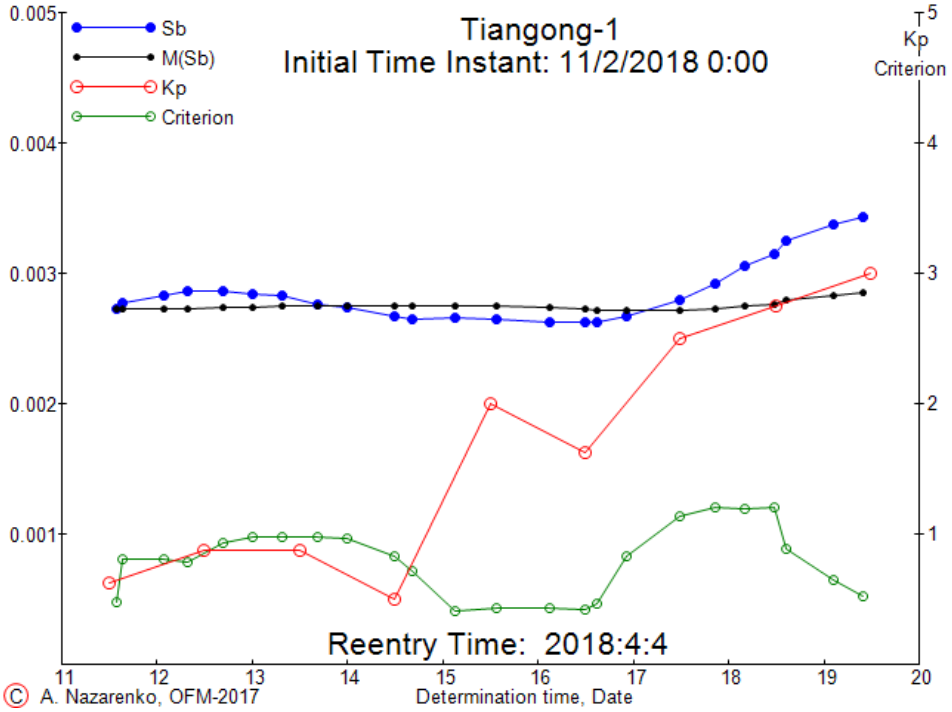

Figure 1. Values of ballistic coefficient, Kp and minimized criterion

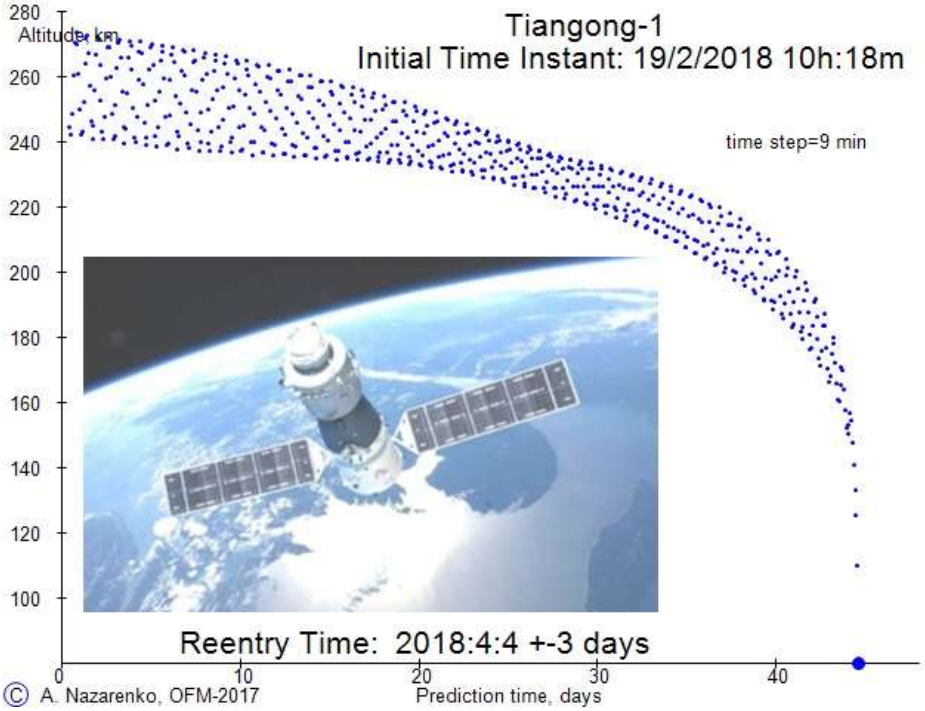

Figure 2. Change of the altitude on the prediction interval

Reentry Information.

Tianging-1 is predicted to reenter on April 4, 2018 ±3 days.

Figure 3 presents the results of all 48 preceding determinations of Tiangong-1 SC reentry time after February 01. The average value of reentry time is ≈ April 04. Deviations from the average value do not exceed 10% of remaining lifetime. The RMS of errors amounted **1.6%**, which is several times lower than the traditional

estimates of errors. Reduction of reentry time after February 01 is the consequence of the impact of geomagnetic storms.

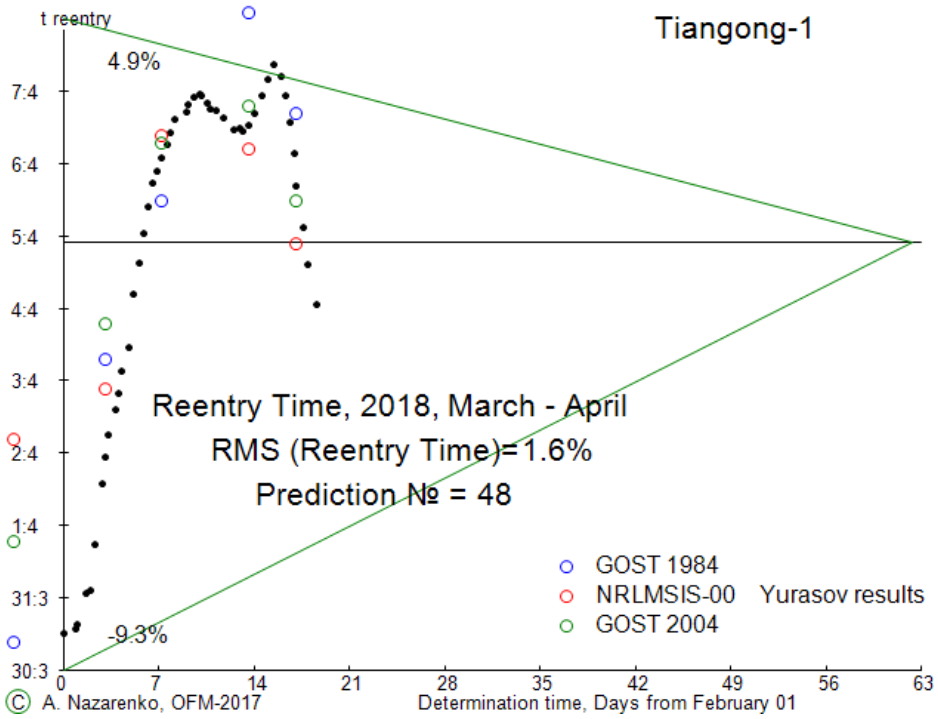

Figure 3. All determinations of Tiangong-1 SC reentry time after February 01

2. Recent publication of other authors

a) Aerospace Corporation

Reentry Information

Tiangong-1 is predicted to reenter in **early April 2018** ± 1.5 weeks*.
This prediction was performed by The Aerospace Corporation on 2018 February 14.

b) Space-Track data [10]

DECAY DATA:

Show 10 entries Search All Columns: 37820

NORAD CAT ID	SATNAME	INTLDES	COUNTRY	MSG_EPOCH	DECAY_EPOCH	RCS	SOURCE	TLE	Type
37820	TIANGONG 1	2011-053A	PRC	2018-01-31 17:25:58	2018-03-12 0:00:00	LARGE	6Oday_msg	TLE	Prediction
37820	TIANGONG 1	2011-053A	PRC	2018-01-24 16:00:44	2018-03-12 0:00:00	LARGE	6Oday_msg	TLE	Prediction
37820	TIANGONG 1	2011-053A	PRC	2017-12-27 16:48:42	2018-02-22 0:00:00	LARGE	6Oday_msg	TLE	Prediction
NORAD CAT ID	SATNAME	INTLDES	COUNTRY	MSG_EPOCH	DECAY_EPOCH	RCS	SOURCE		Type

Showing 1 to 3 of 3 entries (filtered from 57,921 total entries) First Previous 1 Next Last

Country Legend RCS Legend

c) Data by V.S. Yurasov (private message).

The TLE processing results over the preceding week interval and the forecast of the SC motion until reentry:

Initial data time	Results	Atmospheric model		
		GOST 1984	NRLMSIS	GOST 2004
November 9, 2017	t reentry	March **10** 02^h	March **9** 06^h	March **7** 00^h
	Sb, m^2/kg	0.00384	0.00386	0.00368
December 1, 2017	t reentry	March **12** 03^h	March **9** 18^h	March **11** 22^h
	Sb, m^2/kg	0.00361	0.00389	0.00360
December 9, 2017	t reentry	March **14** 00^h	March **16** 12^h	March **18** 06^h
	Sb, m^2/kg	0.00367	0.00373	0.00347
December 19, 2017	t reentry	March **19** 14^h	March **21** 03^h	March **17** 14^h
	Sb, m^2/kg	0.00349	0.00361	0.00359
December 28, 2017	t reentry	March **19** 20^h	March **20** 18^h	March **20** 15^h
	Sb, m^2/kg	0.00347	0.00369	0.00346
January 12, 2018	t reentry	March **28** 10^h	March **30** 22^h	March **30** 10^h
	Sb, m^2/kg	0.00331	0.00341	0.00325
January 23, 2018	t reentry	March **28** 09^h	March **28** 22^h	March **29** 22^h
	Sb, m^2/kg	0.00348	0.00342	0.00369
January 27, 2018	t reentry	March **30** 04^h	April **02** 20^h	March **31** 04^h
	Sb, m^2/kg	0.00334	0.00334	0.00333
February 4 2018	t reentry	April **03** 23^h	April **04** 19^h	April **03** 08^h
	Sb, m^2/kg	0.0032	0.0034	0.0032
February 8 2018	t reentry	April **05** 12^h	April **06** 8^h	April **06** 07^h
	Sb, m^2/kg	0.0030	0.0032	0.0030
February 18 2018	t reentry	April **06** 17^h	April **04** 23^h	April **05** 13^h
	Sb, m^2/kg	0.0030	0.0033	0.0031

d) ESA (http://blogs.esa.int/rocketscience/2018/01/12/tiangong-1-reentry-updates/)

Update 7 February 2018

The current estimated window is **~25 March to ~17 April**; this is highly variable.

Reentry will take place anywhere between 43ºN and 43ºS (e.g. Spain, France, Portugal, Greece, etc.). Areas outside of these latitudes can be excluded. At no time will a precise time/location prediction from ESA be possible. This forecast will be updated approximately every week in January and February.

References

1. A.I. Nazarenko. Decay Epoch of the "Tiangong-1" Spacecraft. November 1, 2017.
2. A.I. Nazarenko. Decay Epoch of the "Tiangong-1" Spacecraft. November 15, 2017.
3. A.I. Nazarenko. Decay Epoch of the "Tiangong-1" Spacecraft. December 1, 2017.
4. A.I. Nazarenko. Decay Epoch of the "Tiangong-1" Spacecraft. December 10, 2017.
5. A.I. Nazarenko. Decay Epoch of the "Tiangong-1" Spacecraft. December 20, 2017.
6. A.I. Nazarenko. Decay Epoch of the "Tiangong-1" Spacecraft. December 30, 2017.
7. A.I. Nazarenko. Decay Epoch of the "Tiangong-1" Spacecraft. January 15, 2018.
8. A.I. Nazarenko. Decay Epoch of the "Tiangong-1" Spacecraft. January 30, 2018
9. A.I. Nazarenko. Decay Epoch of the "Tiangong-1" Spacecraft. February 10, 2018
10. http://www.space-track.org