esoc

European Space Operations Centre
Robert-Bosch-Strasse 5
D-64293 Darmstadt
Germany
T +49 (0)6151 900
F +49 (0)6151 90495
www.esa.int

DOCUMENT

ExoMars 2016: TGO and EDM trajectory states for March 2016 Launch

Prepared by Robert Guilanyà
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APPROVAL

Title	
Issue 4.1	**Revision**
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CHANGE LOG

Reason for change	Issue	Revision	Date
Add states for Launch Window close	3	0	16/10/2015
Update state vector at Pre Separation for the Launch 25th March in EME2000 ref frame	3	1	20/10/2015
Update trajectory from the new inputs on the EXM-DM-ICD-AI-0050 issue 3 and the updates for March Launch	4	0	27/11/2015
Add Delta-V received on the EDM	4	1	05/12/2015

CHANGE RECORD

Issue 3	**Revision 0**		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Add chapter 3 with information on the Launch on 25th March	16/10/2015	from 7 onwards	
Issue 3	**Revision 1**		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Update Table	20/10/2015	8	
Issue 4	**Revision 0**		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Update all tables based on new trajectory inputs and add chapters 2.4 and 3.4	27/11/2015	from 4 onwards	
Issue 4	**Revision 1**		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Add tables which contain the Delta-V received on the EDM	05/12/2015	6, 8, 10, 12	

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1 INTRODUCTION

The information contained in this document is generated based on the latest state vector at separation from the launcher authority R1.
The information is consistent with the Trajectory Datapack delivered on the 27th November for the Launch on 14th March and 25th March.
The Datapack only contains information on the nominal sequence.

1.1 References

R1: Email from S.Bayon 28th September to M.Khan, M.Denis and R.Guilanya, “updated SC state vector and LV launch time”.

2 LAUNCH 14TH MARCH

2.1 TGO Manoeuvre s schedule

2.1.1 State vector at launcher separation

State vector at Launcher separation	
Time (UTC)	2016-03-14T20:13:01.000
Px (EME2000 Earth Centered) (km)	-8297.6405
Py (EME2000 Earth Centered) (km)	7590.0945
Pz (EME2000 Earth Centered) (km)	1515.2410
Vx (EME2000 Earth Centered) (km/s)	-7.8169222357
Vy (EME2000 Earth Centered) (km/s)	1.1579047851
Vz (EME2000 Earth Centered) (km/s)	-4.6464639754

2.1.2 Deterministic manoeuvres

Test RCT Manoeuvre	
Start Time (UTC)	2016-03-17T10:00:00.000
Delta-V (m/s)	0.5000
Right Ascension (EME2000) (deg)	192.598668838
Declination (EME2000) (deg)	-43.4228899362
Test Main Engine Manoeuvre	
Start Time (UTC)	2016-07-18T12:00:00.000
Delta-V (m/s)	1.000
Right Ascension (EME2000) (deg)	13.9627969571
Declination (EME2000) (deg)	-19.5861514070
DSM-1	
Start Time (UTC)	2016-07-28T12:00:00.000
Delta-V (m/s)	326.497300220
Right Ascension (EME2000) (deg)	19.5000690123
Declination (EME2000) (deg)	-19.4201944653
DSM-2	
Start Time (UTC)	2016-08-11T12:48:58.246
Delta-V (m/s)	17.184068433
Right Ascension (EME2000) (deg)	21.5212219452
Declination (EME2000) (deg)	-18.7069814269
EDM Separation (delta-V received on TGO)	
Time (UTC)	2016-10-16T14:42:11.718
Delta-V (m/s)	0.072456950
Right Ascension (EME2000) (deg)	79.9842800321
Declination (EME2000) (deg)	13.2165451716
Orbiter Retargeting Manoeuvre	
Start Time (UTC)	2016-10-17T02:42:11.718
Delta-V (m/s)	10.776458532
Right Ascension (EME2000) (deg)	205.7486506762
Declination (EME2000) (deg)	10.8489171584
Mars Orbit Insertion	
Start Time (UTC)	2016-10-19T13:09:40.284
End Time (UTC)	2016-10-19T15:23:16.940

Delta-V (m/s)	1552.731180451
Right Ascension (EME2000) (deg)	Opposite to the velocity vector
Declination (EME2000) (deg)	Opposite to the velocity vector
Inclination Change Manoeuvre	
Start Time (UTC)	2017-01-11T07:48:21.891
Delta-V (m/s)	203.787889222
Right Ascension (EME2000) (deg)	219.1462273726
Declination (EME2000) (deg)	-63.6839424350
Apocenter Lowering Manoeuvre	
Start Time (UTC)	2017-01-17T10:46:16.869
Delta-V (m/s)	133.564213684
Right Ascension (EME2000) (deg)	121.5129665853
Declination (EME2000) (deg)	-38.5504998566

2.1.3 Stochastic manoeuvres

LIC	Around 7 days after Launch. Date optimized to minimize fuel
TCM-1	10 days after LIC
TCM-2	10 days after DSM-2
TCM-3	30 days before landing
TCM-4	5 days before landing

2.2 State vector at EDM pre-separation

State vector at EDM Pre-Separation	
Time (UTC)	2016-10-16T14:42:11.718
Px (EME2000 Mars Centered) (km)	473370.7309
Py (EME2000 Mars Centered) (km)	784347.8187
Pz (EME2000 Mars Centered) (km)	8450.6701
Vx (EME2000 Mars Centered) (km/s)	-1.8154984425
Vy (EME2000 Mars Centered) (km/s)	-2.9702750945
Vz (EME2000 Mars Centered) (km/s)	-0.0201933083

2.3 EDM Separation Delta-V

EDM Separation (delta-V received on the EDM)	
Time (UTC)	2016-10-16T14:42:11.718
Delta-V (m/s)	0.321643050
Right Ascension (EME2000) (deg)	259.9842800260
Declination (EME2000) (deg)	-13.2165451661

2.4 State vector at ECP

State vector at ECP	
Time (UTC)	2016/10/19_14:42:10.504
Radius (km)	3517.5150
Longitude (deg E)	342.5289548367
Latitude (deg N)	-3.6288923421
Relative velocity (km/s)	5.7928701094
Relative FPA (deg)	-12.4811570490
Azimuth (deg from N)	82.3835030733

2.5 Contingency EDM separation

2.5.1 Manoeuvre sequence

TCM-Retargeting contingency	
Start Time (UTC)	2016-10-17T14:42:11.718
Delta-V (m/s)	0.220339942
Right Ascension (EME2000) (deg)	258.6803939423
Declination (EME2000) (deg)	-12.6872744159
EDM Separation (delta-V received on TGO)	
Time (UTC)	2016-10-17T22:42:11.704
Delta-V (m/s)	0.072461421
Right Ascension (EME2000) (deg)	79.9841343401
Declination (EME2000) (deg)	13.2164777853
Orbiter Retargeting Manoeuvre	
Start Time (UTC)	2016-10-18T06:42:11.704
Delta-V (m/s)	19.879295079
Right Ascension (EME2000) (deg)	205.6813822984
Declination (EME2000) (deg)	11.2150433655
Mars Orbit Insertion	
Start Time (UTC)	2016-10-19T13:10:23.969
Start Time (UTC)	2016-10-19T15:23:56.299
Delta-V (m/s)	1558.245679608
Right Ascension (EME2000) (deg)	Opposite to the velocity vector
Declination (EME2000) (deg)	Opposite to the velocity vector
Inclination Change Manoeuvre	
Start Time (UTC)	2017-01-11T08:09:13.294
Delta-V (m/s)	204.043897111
Right Ascension (EME2000) (deg)	218.7407632958
Declination (EME2000) (deg)	-63.3486210850
Apocenter Lowering Manoeuvre	
Start Time (UTC)	2017-01-17T11:06:38.449
Delta-V (m/s)	133.489650117
Right Ascension (EME2000) (deg)	121.1139200527

Declination (EME2000) (deg)	-38.7289282946

2.5.2 State Vector at EDM separation

State vector at EDM Pre-Separation	
Time (UTC)	2016-10-17T22:42:11.704
Px (EME2000 Mars Centered) (km)	263939.4821
Py (EME2000 Mars Centered) (km)	441677.3065
Pz (EME2000 Mars Centered) (km)	6115.3489
Vx (EME2000 Mars Centered) (km/s)	-1.8214463682
Vy (EME2000 Mars Centered) (km/s)	-2.9805788443
Vz (EME2000 Mars Centered) (km/s)	-0.0203975495

2.5.3 EDM Separation Delta-V

EDM Separation (delta-V received on the EDM)	
Time (UTC)	2016-10-17T22:42:11.704
Delta-V (m/s)	0.321638579
Right Ascension (EME2000) (deg)	259.9841343401
Declination (EME2000) (deg)	-13.2164777853

2.5.4 State Vector at ECP

State vector at ECP	
Time (UTC)	2016/10/19_14:42:10.491
Radius (km)	3517.5150
Longitude (deg E)	342.5288412053
Latitude (deg N)	-3.6289000927
Relative velocity (km/s)	5.7929871944
Relative FPA (deg)	-12.4811584839
Azimuth (deg from N)	82.3835452543

3 LAUNCH 25TH MARCH

3.1 TGO Manoeuvre s schedule

3.1.1 State vector at launcher separation

State vector at Launcher separation	
Time (UTC)	2016-03-25T21:34:55.000
Px (EME2000 Earth Centered) (km)	-9862.1904
Py (EME2000 Earth Centered) (km)	4718.0353
Pz (EME2000 Earth Centered) (km)	3437.9817
Vx (EME2000 Earth Centered) (km/s)	-8.5991605635
Vy (EME2000 Earth Centered) (km/s)	-0.9710467929
Vz (EME2000 Earth Centered) (km/s)	-3.2856055612

3.1.2 Deterministic manoeuvres

Test RCT Manoeuvre	
Start Time (UTC)	2016-03-28T10:00:00.000
Delta-V (m/s)	0.5000
Right Ascension (EME2000) (deg)	202.0750512477
Declination (EME2000) (deg)	-34.4767240962
Test Main Engine Manoeuvre	
Start Time (UTC)	2016-08-08T12:00:00.000
Delta-V (m/s)	1.000
Right Ascension (EME2000) (deg)	64.4407830313
Declination (EME2000) (deg)	-4.5294502251
DSM-1	
Start Time (UTC)	2016-08-18T12:00:00.000
Delta-V (m/s)	204.724492931
Right Ascension (EME2000) (deg)	65.1401347153
Declination (EME2000) (deg)	-4.2008556485
DSM-2	
Start Time (UTC)	2016-09-01T12:31:17.977
Delta-V (m/s)	10.774973312
Right Ascension (EME2000) (deg)	63.3093093228
Declination (EME2000) (deg)	-4.9032426214
EDM Separation (delta-V received on TGO)	
Time (UTC)	2016-10-16T14:31:49.416
Delta-V (m/s)	0.070112906
Right Ascension (EME2000) (deg)	72.5354134042
Declination (EME2000) (deg)	20.3591210619
Orbiter Retargeting Manoeuvre	
Start Time (UTC)	2016-10-17T02:31:49.416
Delta-V (m/s)	12.695827361
Right Ascension (EME2000) (deg)	211.8971244675
Declination (EME2000) (deg)	15.4875630294
Mars Orbit Insertion	
Start Time (UTC)	2016-10-19T12:47:04.957
End Time (UTC)	2016-10-19T15:13:18.717

Delta-V (m/s)	1642.04963208
Right Ascension (EME2000) (deg)	Opposite to the velocity vector
Declination (EME2000) (deg)	Opposite to the velocity vector
Inclination Change Manoeuvre	
Start Time (UTC)	2017-01-11T07:08:58.028
Delta-V (m/s)	212.424448984
Right Ascension (EME2000) (deg)	286.7631808404
Declination (EME2000) (deg)	20.6798255771
Apocenter Lowering Manoeuvre	
Start Time (UTC)	2017-01-17T09:52:36.027
Delta-V (m/s)	133.894164750
Right Ascension (EME2000) (deg)	344.8241498768
Declination (EME2000) (deg)	65.0269784535

3.1.3 Stochastic manoeuvres

LIC	Around 7 days after Launch. Date optimized to minimize fuel
TCM-1	10 days after LIC
TCM-2	10 days after DSM-2
TCM-3	30 days before landing
TCM-4	5 days before landing

3.2 State vector at EDM pre-separation

State vector at EDM Pre-Separation	
Time (UTC)	2016-10-16T14:31:49.416
Px (EME2000 Mars Centered) (km)	568724.1770
Py (EME2000 Mars Centered) (km)	740127.9759
Pz (EME2000 Mars Centered) (km)	111239.1489
Vx (EME2000 Mars Centered) (km/s)	-2.1786878475
Vy (EME2000 Mars Centered) (km/s)	-2.8048104050
Vz (EME2000 Mars Centered) (km/s)	-0.4099032721

3.3 EDM Separation Delta-V

EDM Separation (delta-V received on the EDM)	
Time (UTC)	2016-10-16T14:31:49.416
Delta-V (m/s)	0.323987094
Right Ascension (EME2000) (deg)	252.5354134112
Declination (EME2000) (deg)	-20.3591210649

3.4 State vector at ECP

State vector at ECP	
Time (UTC)	2016/10/19_14:31:48.213
Radius (km)	3517.5150
Longitude (deg E)	342.3785237797
Latitude (deg N)	-1.6019776142

Relative velocity (km/s)	5.8455096826
Relative FPA (deg)	-12.4818850770
Azimuth (deg from N)	92.35654537710

3.5 Contingency EDM separation

3.5.1 Manoeuvre sequence

TCM-Retargeting contingency	
Start Time (UTC)	2016-10-17T14:31:49.416
Delta-V (m/s)	0.221985307
Right Ascension (EME2000) (deg)	251.2412274299
Declination (EME2000) (deg)	-19.8329335401
EDM Separation (delta-V received on TGO)	
Time (UTC)	2016-10-17T22:31:49.397
Delta-V (m/s)	0.070117300
Right Ascension (EME2000) (deg)	72.5352311353
Declination (EME2000) (deg)	20.3590472375
Orbiter Retargeting Manoeuvre	
Start Time (UTC)	2016-10-18T06:31:49.397
Delta-V (m/s)	23.424168008
Right Ascension (EME2000) (deg)	211.4782099111
Declination (EME2000) (deg)	15.3683717370
Mars Orbit Insertion	
Start Time (UTC)	2016-10-19T12:48:15.446
End Time (UTC)	2016-10-19T15:14:23.948
Delta-V (m/s)	1649.078464984
Right Ascension (EME2000) (deg)	Opposite to the velocity vector
Declination (EME2000) (deg)	Opposite to the velocity vector
Inclination Change Manoeuvre	
Start Time (UTC)	2017-01-11T07:41:18.725
Delta-V (m/s)	212.600268076
Right Ascension (EME2000) (deg)	286.1969764522
Declination (EME2000) (deg)	20.9955708567
Apocenter Lowering Manoeuvre	
Start Time (UTC)	2017-01-17T10:24:20.471
Delta-V (m/s)	133.769652761
Right Ascension (EME2000) (deg)	345.3068281586
Declination (EME2000) (deg)	64.6795519924

3.5.2 State Vector at EDM separation

State vector at EDM Pre-Separation	
Time (UTC)	2016-10-17T22:31:49.397
Px (EME2000 Mars Centered) (km)	317432.9724
Py (EME2000 Mars Centered) (km)	416566.6332

Pz (EME2000 Mars Centered) (km)	63944.6539
Vx (EME2000 Mars Centered) (km/s)	-2.1851361452
Vy (EME2000 Mars Centered) (km/s)	-2.8140593799
Vz (EME2000 Mars Centered) (km/s)	-0.4114282620

3.5.3 EDM Separation Delta-V

EDM Separation (delta-V received on the EDM)	
Time (UTC)	2016-10-17T22:31:49.397
Delta-V (m/s)	0.323982700
Right Ascension (EME2000) (deg)	252.5352311353
Declination (EME2000) (deg)	-20.3590472375

3.5.4 State Vector at ECP

State vector at ECP	
Time (UTC)	2016/10/19_14:31:48.19447
Radius (km)	3517.5150
Longitude (deg E)	342.3784085098
Latitude (deg N)	-1.6019668263
Relative velocity (km/s)	5.8456302480
Relative FPA (deg)	-12.4818865187
Azimuth (deg from N)	92.3565760088