Conjunction Assessment Process For Mars Orbiters

Revision 3

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May 2022
D-93790, Revision 3

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URS309986 CL#22-3991

DOCUMENT CHANGE LOG

DATE	PAGES AFFECTED	REASON FOR CHANGE	VERSION/ REVISION
5/28/2014	All	Initial version	Initial
1/31/2015	14-17	Added Appendix	1
1/8/2018	8, 9-10, 13	Clarified Response Process Flowchart. Updated monitoring and response notification lists. Updated Sample Monitoring Message	2
5/26/2022	All	Periodic update for currency, major revisions to reflect actual practice	3

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1 Introduction and Brief History

In May 2005, Mars Odyssey and Mars Express (MEX) experienced a close approach (<10km with orbit crossing <1km). Uncertainties in the MEX trajectory led ESA to perform an avoidance maneuver. No formal process was in place at that time. In mid-2006, the MRO navigation team developed a collision avoidance (COLA) process that was used initially during aerobraking operations. MRO performed 27 aerobraking maneuvers, six of which were executed to avoid possible collisions with other spacecraft. In summer 2011, the MADCAP process (MArs Deepspace Collision Avoidance Program) was instituted for regular weekly monitoring of Mars Odyssey, Mars Express, and Mars Reconnaissance Orbiter. [Note: Earlier versions of the MADCAP process were referred to as a Mars COLlision Avoidance (COLA) process.] Non-operating spacecraft such as MGS and the Viking 1 orbiter were also included. The process was progressively formalized. In June 2012, the process was presented at the SpaceOps Conference in Stockholm, Sweden. In early 2014, the first version of this document formalizing the process was negotiated (see Document "Change Log" above for subsequent revision history). In late 2014, a new release of the MADCAP software was produced in preparation for the arrival of MAVEN and MOM at Mars; MADCAP was re-christened "Multimission Automated Deepspace Conjunction Assessment Process". Since that time, approximately annual software updates have been implemented with bug fixes and improvements to scheduling, processing, reports, and report distribution lists. Several conference papers have reported MADCAP progress (see "References").

This document describes the conjunction assessment process that routinely monitors Mars-orbiting spacecraft trajectories for future orbit crossings and close approaches, as it exists today; there have been several changes to the initially negotiated process based on the reality of Mars orbiter operations (e.g., the original process involved the MPO in setting up meetings to discuss maneuvers upon each "red event"; in practice this has not been necessary). The process uses the aforementioned MADCAP automated navigation utility that executes on secure flight network computers at JPL. MADCAP is built upon JPL's Monte multimission navigation software. Requirements, a technical description, and user guide for MADCAP are available in the EPDM. The process takes advantage of and depends on the availability ephemeris predictions provided to the DSN by flight projects (including non-NASA vehicles) for tracking and communications support. Summary Reports are sent to stakeholders by email via tailored email lists.

The process consists of Monitoring and Response Functions (see Section 3). The Monitoring Function is implemented via a daily Summary Report emailed to interested parties. The Response Function is invoked when there is a red event reported in the Summary Report. In these cases, a JPL MDNAV MADCAP Representative will work with the navigation team(s) involved to determine a course of action. In some cases, collision avoidance maneuvers are negotiated between the affected flight project teams. In the event a response plan cannot be agreed upon by the affected flight projects, the Manager of the Mars Program Office (MPO) will determine the final response via a Conflict Resolution Process.

This document formalizes the conjunction assessment process in use for missions currently in orbit at Mars. As spacecraft (including non-NASA missions) are added to the existing fleet in orbit at Mars, every effort will be made to include them in this process.

A virtually identical process is also in use for Lunar orbiters and objects at Sun/Earth Lagrange Points.

2 Driving Requirements

1. The MADCAP shall perform conjunction assessment analyses routinely for all maneuverable Mars orbiting spacecraft and natural satellites. (MADCAP Requirements A.015, M.067, A.030)

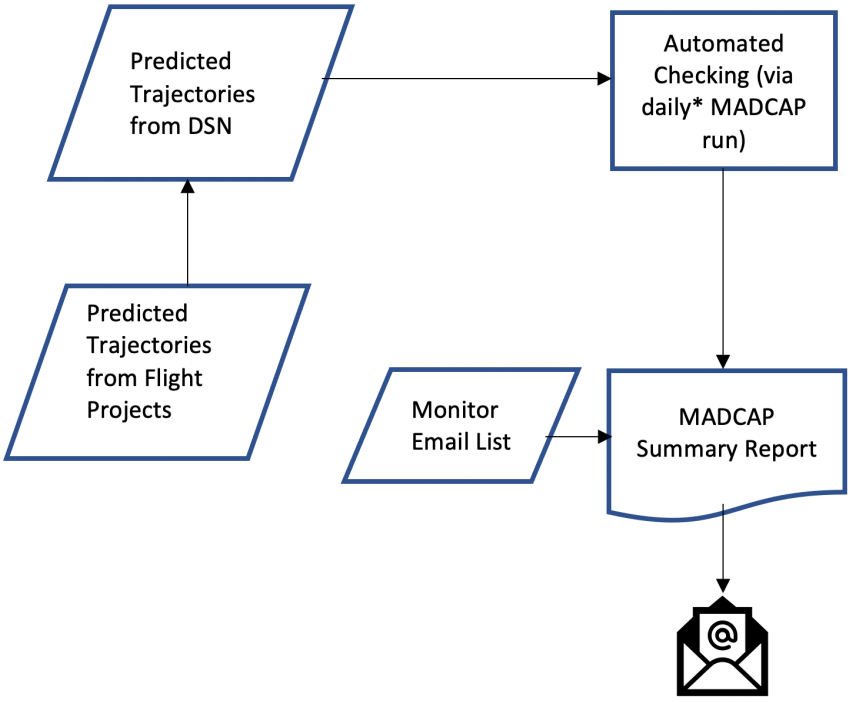
2. The MADCAP shall identify potentially high risk Mars orbiter close approaches and communicate any to key stakeholders sufficiently in advance to enable an avoidance response. (MADCAP Requirements G.017, R.005)

3. The MADCAP shall maintain (on best efforts basis) estimated locations of non-functioning Mars-orbiting spacecraft. (MADCAP Requirement G.020)

3 Procedure

MONITORING FUNCTION		
Step	**Who**	**Action**
1	JPL MDNAV (Mission Design and Navigation) MADCAP Rep	Ensure routine daily execution of monitoring software to identify predicted close approaches (orbit crossing distances and orbit crossing timings). Provide daily summary to “Monitoring” group. (See Section 4.)
2	MDNAV MADCAP Rep	Invoke "Response Function" when the daily summary report shows that any close approach (orbit crossing distance AND orbit crossing timing) within 14 days from run time falls below pre-defined thresholds (hereafter called a "red event").
RESPONSE FUNCTION		
3	MDNAV MADCAP Rep	Communicate with affected NAV Team Chiefs within 24 hours to confirm that they are aware of the reported red event.
4	MDNAV MADCAP Rep and Flight Project Navigation (NAV) Reps	Discuss options and agree to recommended response actions to red event, which may include actions by at least one and possibly both flight projects. Obtain approvals as necessary. Depending on the time-to-go until the red event, "watch" may be the initial action.
5	MDNAV MADCAP Rep	Within 24 hours of discussing with NAV Team Chiefs, communicate reported red event and proposed action outcome to the identified “Response” group. (See Section 5.) Invoke "Conflict Resolution Function" in the event that agreement on action cannot be obtained.
6	Flight Project(s) Nav	Prepare to implement agreed response action(s), e.g., design, build, and test of avoidance maneuver (if applicable).
7	All	Continue Monitoring Function while response action is prepared
8	MDNAV MADCAP Rep	If response involves a maneuver, and if requested by flight project(s), execute a MADCAP test run (on a best effort basis) to confirm planned avoidance maneuver (a) mitigates red event risk and (b) no new threshold violations result.
9	Flight Project(s)	Implement agreed response action(s) if/when desirable or necessary. Confirm proper execution.
10	All	Continue Monitoring Function (end of process).
CONFLICT RESOLUTION FUNCTION		
N/A	N/A	Next steps are conditional and only exercised if the normal process fails (e.g., high criticality event, flight projects cannot agree on response actions, there is disagreement with proposed response actions, lack of response by a flight project involved in red event, etc.)
11	MDNAV MADCAP Rep	Convene a meeting with decision makers of affected flight project teams. Discuss issues with candidate response actions. Negotiate and iterate until agreement is reached. This may involve concurrence with the NAV recommendation or an alternate response. This process may have to be modified for red events that do not involve NASA satellites. Determine appropriate escalation if agreement cannot be reached.
12	MDNAV MADCAP Rep	Communicate agreed action outcome to the identified “Response” group. (See Section 5.)
13	All	Go to Step 5 of Response Function.

4 Monitoring Function (Daily*)



*Frequency of execution used for current Mars orbiters. Frequency can be increased/decreased if conditions render it necessary or desirable. Red event threshold values are based on each Project's three-sigma trajectory uncertainty estimates and are provided by the Project to the MADCAP Team.

The MADCAP Summary Report is emailed to interested parties maintained in an email list (mars_madcap_monitor@list.jpl.nasa.gov) maintained by the MDNAV MADCAP Representative. It is essentially open to subscription by parties interested in the Mars orbital environment. It provides information about pairwise orbit crossing distances, orbit crossing timing, and closest approaches based on flight project determined thresholds. Lander and flyby missions are included in MADCAP analyses during final approach. The organizations and personnel represented in this list (as of publication date) include at least:

- Mars Program Office Representatives
- Mars Orbiter Flight Projects (modified as missions are added/retired):
  - NASA Mars Odyssey (ODY)
  - ESA Mars Express (MEX)
  - NASA Mars Reconnaissance Orbiter (MRO)
  - NASA Mars Atmosphere and Volatile Evolution (MAVEN)
  - ISRO Mars Orbiter Mission (MOM)
  - ESA ExoMars Trace Gas Orbiter (TGO)
  - UAESA/Hope
  - CNSA/Tianwen-1 (Note: Special distribution mechanism for this report recipient)
- JPL MDNAV Section Management Team
- MGSS Program Office
- NASA CARA Representative
- MADCAP Representatives

5 Response Notifications

The Response Report is sent to designated leadership with respect to the missions involved in a MADCAP "red event" (i.e., orbit crossing distance AND orbit crossing timing both below mission defined thresholds within 14 days from run time). A list of designated recipients for each interest group is maintained by the MDNAV MADCAP representative. Missions indicate who they would like to receive the red event messages. "Response" notifications are tailored for the missions involved in the red event and include a preliminary recommendation for addressing the situation (see Section 9). The organizations that are represented in this list (as of publication date) include:

- Mars Orbiter Flight Projects (generally two of the following):
  - NASA Mars Odyssey (ODY)
  - ESA Mars Express (MEX)
  - NASA Mars Reconnaissance Orbiter (MRO)
  - NASA Mars Atmosphere and Volatile Evolution (MAVEN)
  - ISRO Mars Orbiter Mission (MOM)
  - ESA ExoMars Trace Gas Orbiter (TGO)
  - UAESA/Hope
  - CNSA/Tianwen-1 (Note: Special distribution mechanism for this report recipient... recipients also include NASA/Office of International and Interagency Relations)
- Mars Exploration Program Office Representatives
- JPL MDNAV Section Management Team
- MGSS Program Office
- NASA CARA Representative
- MADCAP Representatives

6 Non-NASA Vehicles Considerations

Non-NASA Mars spacecraft (e.g., ESA/Mars Express, ISRO/MOM, ESA/TGO, etc.) will be included in the MADCAP process to the extent that accurate trajectory prediction information is available. Use of the DSN for tracking and communication services by those missions facilitates but is not required for the Monitoring and Response functions.

7 Inactive Vehicles Considerations

Conjunction events for inactive Mars orbiters are not included in the summary reporting messages. However, for MGS (Mars Global Surveyor) and Viking 1/2, end-of-mission orbital states are used to produce long-term future predictions of orbit crossings and close approach estimates and are available upon request. Given the large orbital uncertainties the orbit crossing and close approach data are of marginal value. Bands of inclination may be the only useful information.

8 Natural Body Considerations

Ephemerides for the Mars natural satellites Phobos and Deimos are used in the daily analyses; these are prepared by the Solar System Dynamics group in the MDN Section and used in Mars orbiter operations. Conjunctions of a spacecraft and one of the satellites are included in the summary reporting messages. Special considerations in threshold settings are necessary for the natural satellites given that (a) the ephemeris position is predicted with respect to the center of gravity of the body, and (b) the body has significant size compared to a spacecraft, and unlike a spacecraft cannot be treated as essentially a point mass.

9 Sample Response Message (Associated w/Next Section)

From: David Berry <david.s.berry@jpl.nasa.gov>
Date: Thursday, July 9, 2020 at 3:18 PM
To: <<list of recipients based on conjunction>>
Subject: FW: MADCAP -- Mars -- Summary -- 1 Red

All,

In today's MADCAP Summary report (shown below) one Red event was triggered for Odyssey/MAVEN on 2020-07-23.

The recommendation at this time is:

- COLLISION AVOIDANCE ACTION is **watch** this predicted close approach.

Justification for Recommendation
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This event is at the 14-day red event boundary, and in that span of time conditions often change between the analysis and the predicted event. According to the MAVEN Navigation Team Chief, the MAVEN team will have maneuver opportunities for this over a week in the future, at which time they will look at this in detail and plan to take action if the red event persists.

Background
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Per the Conjunction Assessment Process for Mars Orbiters (JPL D-93790, Revision 2, 2018-01-08), a recommended response by the MDNAV MADCAP representative and the navigation teams involved is required when a close approach is predicted in less than 14 days to be within pre-defined threshold values. These events are flagged as "Red" events in the daily monitor email sent to the Mars MADCAP monitor mail list.

Regards,
David Berry
MDNAV MADCAP Representative

10 Sample Monitor Message: Red Event with 2 Spacecraft

Analysis Time: 2020-07-09 21:30:20 UTC

```
RED Threshold Updates: 0
ALL Threshold Updates: 0
Ephemeris Updates:     2
```

Conjunction Assessment Bodies and Types

Body	Name	Type
1	Odyssey	Active
1r	Odyssey	Active/Reference
2	Mars_Express	Active
3	MRO	Active
4	MAVEN	Active
5	MOM	Active
6	TGO	Active
7	Phobos	Natural
8	Deimos	Natural
9	Viking1	Inactive
10	MGS	Inactive

Red (Conjunction Data < 'Red' Thresholds and Event < 14 days from Analysis Time)

Bodies	OXD value/limit (km)			OXT value/limit (sec)			CAD value/limit (km)			CA Epoch (UTC-SCET)
1-4	1.5	4.1	4P	168.6	257.4	4P	292.1	-----	--	2020-07-23 00:25:39

All (Conjunction Data < 'All' Thresholds for <= 100 days)

Bodies	OXD (km)	OXT (sec)	CAD (km)	CA Epoch (UTC-SCET)
1-4	-4.3	-1105.7	1893.4	2020-07-22 20:39:41
1-4	-2.1	6004.6	2787.9	2020-07-22 21:37:12
1-4	1.5	168.6	292.1	2020-07-23 00:25:39
1-4	1.3	7284.4	2703.0	2020-07-23 01:28:10
1-4	2.8	1450.5	2301.4	2020-07-23 04:10:44
3-4	-8.2	-897.2	2289.3	2020-08-06 13:12:00
3-4	-4.2	-393.9	1024.0	2020-08-06 16:51:43
3-4	-2.9	122.1	318.5	2020-08-06 20:31:11
3-4	-1.5	635.4	1631.3	2020-08-07 00:10:32
3-4	-0.8	1138.0	2827.4	2020-08-07 03:49:48
1r-6	8.6	31.4	95.6	2020-08-08 16:35:27

Notes

OXD means "Orbit Crossing Distance". OXT means "Orbit Crossing Timing". CAD means "Close Approach Distance".

Data for active spacecraft and natural bodies are displayed in the tables above. Data for inactive spacecraft are not displayed, but they are available in the conjunction metric tables and plots, which have been stored in the output directory listed below. Data for reference trajectories are not considered for Red events, but are considered in the All section for events not covered by the predicts file. Reference trajectories use the same thresholds as the nominal trajectories.

For more information, please see the point of contact listed below.

Analysis time:	2020-07-09 21:30:20 UTC
Active spacecraft:	Odyssey, Mars Express, MRO, MAVEN, MOM, TGO
Natural bodies:	Phobos, Deimos
Inactive spacecraft:	Viking1, MGS
Output directory:	/nav/home/jplmdnav/MADCAP/Mars/archive
Point of contact:	MADCAP_Mars@jpl.nasa.gov
MADCAP build:	3.0

Red Thresholds -- Polynomial Coefficients

Body	Name	OXD0 (km)	OXD1 (km/t)	OXD2 (km/t^2)	OXT0 (sec)	OXT1 (sec/t)	OXT2 (sec/t^2)
1	Odyssey	0.0050	0.0013	0.0000	0.0705	-0.0411	0.0096
2	Mars_Express	1.0000	0.0000	0.0000	10.0000	0.0000	0.0000
3	MRO	0.0877	-0.0315	0.0040	0.0100	0.4939	0.0765
4	MAVEN	0.5000	0.2300	0.0030	2.1000	2.8000	1.2300
5	MOM	0.2498	0.0014	0.0012	0.0100	33.0089	0.3246
6	TGO	1.0000	0.0000	0.0000	10.0000	0.0000	0.0000
7	Phobos	30.0000	0.0000	0.0000	15.0000	0.0000	0.0000
8	Deimos	40.0000	0.0000	0.0000	20.0000	0.0000	0.0000

Red OX Distance Threshold = OXD0 + (OXD1 * t) + (OXD2 * t^2) [km]
Red OX Timing Threshold = OXT0 + (OXT1 * t) + (OXT2 * t^2) [sec]
where t = CA Epoch - Ephemeris File Submit Time (in days)

Red thresholds are based on 3-sigma values. Thresholds listed as "P" are based on a quadratic fit of the 3-sigma values as a function of time to the event. The polynomial coefficients used are listed in the table above. Lines for coefficients which have been updated since the last run are colored blue, and each line's body is marked with an "*". Thresholds listed as "C" are based on 3-sigma covariance data provided by the mission.

All Thresholds -- Constants

Body	Name	OXD (km)	CAD (km)
1	Odyssey	10	100
2	Mars_Express	10	100
3	MRO	10	300
4	MAVEN	10	3000
5	MOM	20	100
6	TGO	10	100

7	Phobos	45	100
8	Deimos	60	200

All OX Distance Threshold = OXD
All CA Distance Threshold = CAD

All thresholds are always constants. The constants used are listed in the table above. Lines for constants which have been updated since the last run are colored blue, and each line's body is marked with an "*".

Ephemerides

Body	Ephemeris	Submitted	Begin	End
1	p_m_od82331-82333_82666_v1.bsp	2020-07-07 00:35:45 UTC	06-JUL-2020 11:21:50 UTC	02-AUG-2020 23:58:50 UTC
1r	p_m_od82071-82076_83382_v1.bsp_V0.1	Analysis Time	15-JUN-2020 01:45:50 UTC	30-SEP-2020 23:58:50 UTC
2	MOEM_200706OAS_PREDICT__0001.CR.bsp	2020-07-06 10:16:27 UTC	25-JUN-2020 21:48:17 UTC	05-AUG-2020 07:59:17 UTC
3*	pf_psp_rec65401_65399_66364_p-v1.bsp	2020-07-09 16:34:21 UTC	09-JUL-2020 08:55:50 UTC	22-SEP-2020 13:45:50 UTC
4*	trj_orb_11897-11900_12147_v1_mvn.bsp	2020-07-09 16:55:01 UTC	09-JUL-2020 01:04:29 UTC	15-AUG-2020 10:21:11 UTC
5	ISRO-MOM-2020-06-30-OD2436-189-v1.bsp	2020-07-07 17:28:36 UTC	30-JUN-2020 00:00:00 UTC	05-AUG-2020 00:10:00 UTC
6	TOEM_200706OAS_PREDICT__0001.CR.bsp	2020-07-06 09:53:57 UTC	05-JUL-2020 23:50:54 UTC	15-AUG-2020 16:41:20 UTC
7	mar097.2010-2029.bsp	Analysis Time	29-DEC-2009 23:58:53 UTC	01-JAN-2030 23:58:50 UTC
8	mar097.2010-2029.bsp	Analysis Time	29-DEC-2009 23:58:53 UTC	01-JAN-2030 23:58:50 UTC
9	Viking1_200101_210101.boa	Analysis Time	31-DEC-2019 23:58:50 UTC	31-DEC-2020 23:58:50 UTC
10	p_191030-201029-061215_10yr_nominal.nio	Analysis Time	30-OCT-2019 05:28:50 UTC	29-OCT-2020 06:28:50 UTC

Ephemeris files for the bodies analyzed are listed in the table above. Lines for files which have been updated since the last run are colored blue, and each line's body is marked with an "*".

11 Sample Monitor Message: Red Event with 1 Spacecraft, 1 Natural Object

Analysis Time: 2020-05-28 21:30:20 UTC

RED Threshold Updates: 0
ALL Threshold Updates: 0
Ephemeris Updates: 2

Conjunction Assessment Bodies and Types

Body	Name	Type
1	Odyssey	Active
1r	Odyssey	Active/Reference
2	Mars_Express	Active
3	MRO	Active
4	MAVEN	Active
5	MOM	Active
6	TGO	Active
7	Phobos	Natural
8	Deimos	Natural
9	Viking1	Inactive
10	MGS	Inactive

Red (Conjunction Data < 'Red' Thresholds and Event < 14 days from Analysis Time)

Bodies	OXD value/limit (km)			OXT value/limit (sec)			CAD value/limit (km)			CA Epoch (UTC-SCET)
5-7	3.9	30.0	7P	67.4	817.2	5P	73.3	-----	--	2020-06-11 10:57:28

All (Conjunction Data < 'All' Thresholds for <= 100 days)

Bodies	OXD (km)	OXT (sec)	CAD (km)	CA Epoch (UTC-SCET)
4-5	4.6	101.3	256.9	2020-05-31 09:26:22
3-4	-5.0	5677.2	543.5	2020-05-31 20:10:37
3-4	1.4	-574.3	281.8	2020-05-31 23:50:47
3-4	2.0	6154.8	2530.9	2020-06-01 00:50:34
3-4	7.3	-98.2	45.5	2020-06-01 03:30:50
3-4	7.4	6631.0	2828.6	2020-06-01 04:32:44
3-4	7.0	-6360.7	2680.5	2020-06-07 17:10:47
3-4	5.9	370.3	192.5	2020-06-07 18:11:19
4-6	9.0	1906.5	2118.8	2020-06-08 19:10:22
4-6	7.9	702.1	885.1	2020-06-08 22:55:04
1-6	9.4	7050.2	25.3	2020-06-09 01:24:23
4-6	10.0	6585.5	2500.9	2020-06-09 01:40:15
4-6	7.8	-492.8	640.8	2020-06-09 02:40:05
4-6	7.8	5390.8	2501.0	2020-06-09 05:29:03

1-6	9.7	41.7	43.9	2020-06-09	06:19:52
4-6	3.2	-1695.1	2110.1	2020-06-09	06:26:17
1-6	9.3	-7040.0	89.4	2020-06-09	07:19:04
1-6	9.3	77.5	80.8	2020-06-09	08:18:08
4-6	3.7	4187.6	2718.0	2020-06-09	09:16:12
4-6	0.7	1791.4	1972.8	2020-06-09	16:46:48
4-6	0.1	7672.8	2900.6	2020-06-09	19:26:42
4-6	-2.4	585.4	725.9	2020-06-09	20:31:30
5-7	3.9	67.4	73.3	2020-06-11	10:57:28

Notes

OXD means "Orbit Crossing Distance". OXT means "Orbit Crossing Timing". CAD means "Close Approach Distance".

Data for active spacecraft and natural bodies are displayed in the tables above. Data for inactive spacecraft are not displayed, but they are available in the conjunction metric tables and plots, which have been stored in the output directory listed below. Data for reference trajectories are not considered for Red events, but are considered in the All section for events not covered by the predicts file. Reference trajectories use the same thresholds as the nominal trajectories.

For more information, please see the point of contact listed below.

Analysis time:	2020-05-28 21:30:20 UTC
Active spacecraft:	Odyssey, Mars Express, MRO, MAVEN, MOM, TGO
Natural bodies:	Phobos, Deimos
Inactive spacecraft:	Viking1, MGS
Output directory:	/nav/home/jplmdnav/MADCAP/Mars/archive
Point of contact:	MADCAP Mars@jpl.nasa.gov
MADCAP build:	3.0

Red Thresholds -- Polynomial Coefficients

Body	Name	OXD0 (km)	OXD1 (km/t)	OXD2 (km/t^2)	OXT0 (sec)	OXT1 (sec/t)	OXT2 (sec/t^2)
1	Odyssey	0.0009	0.0013	0.0000	0.0705	-0.0411	0.0096
2	Mars_Express	1.0000	0.0000	0.0000	10.0000	0.0000	0.0000
3	MRO	0.0877	-0.0315	0.0040	0.0100	0.4939	0.0765
4	MAVEN	0.5000	0.2300	0.0030	2.1000	2.8000	1.2300
5	MOM	0.2498	0.0014	0.0012	0.0100	33.0089	0.3246
6	TGO	1.0000	0.0000	0.0000	10.0000	0.0000	0.0000
7	Phobos	30.0000	0.0000	0.0000	15.0000	0.0000	0.0000
8	Deimos	40.0000	0.0000	0.0000	20.0000	0.0000	0.0000

Red OX Distance Threshold = OXD0 + (OXD1 * t) + (OXD2 * t^2) [km]
Red OX Timing Threshold = OXT0 + (OXT1 * t) + (OXT2 * t^2) [sec]
where t = CA Epoch - Ephemeris File Submit Time (in days)

Red thresholds are based on 3-sigma values. Thresholds listed as "P" are based on a quadratic fit of the 3-sigma values as a function of time to the event. The polynomial coefficients used are listed in the table above. Lines for coefficients which have

been updated since the last run are colored blue, and each line's body is marked with an "*". Thresholds listed as "C" are based on 3-sigma covariance data provided by the mission.

All Thresholds -- Constants

Body	Name	OXD (km)	CAD (km)
1	Odyssey	10	100
2	Mars_Express	10	100
3	MRO	10	300
4	MAVEN	10	3000
5	MOM	20	100
6	TGO	10	100
7	Phobos	45	100
8	Deimos	60	200

All OX Distance Threshold = OXD
All CA Distance Threshold = CAD

All thresholds are always constants. The constants used are listed in the table above. Lines for constants which have been updated since the last run are colored blue, and each line's body is marked with an "*".

Ephemerides

Body	Ephemeris	Submitted	Begin	End
1	p_m_od81833-81835_82168_v1.bsp	2020-05-26 23:11:20 UTC	26-MAY-2020 09:55:35 UTC	22-JUN-2020 23:58:50 UTC
1r	p_m_od81732-81738_82848_v1.bsp_V0.1	Analysis Time	18-MAY-2020 03:38:50 UTC	17-AUG-2020 23:58:50 UTC
2	MOEM_200525OAS_PREDICT__0001.CR.bsp	2020-05-25 14:06:21 UTC	07-MAY-2020 23:42:29 UTC	25-JUN-2020 14:21:45 UTC
3*	pf_psp_rec64862_64857_65825_p-v1.bsp	2020-05-28 16:34:47 UTC	28-MAY-2020 03:28:50 UTC	11-AUG-2020 13:53:50 UTC
4*	trj_orb_11613-11617_11863_v1_mvn.bsp	2020-05-28 17:29:42 UTC	27-MAY-2020 10:30:50 UTC	03-JUL-2020 23:26:50 UTC
5	mom_spk_200512-241210_isroOD-200518_dsn.bsp	2020-05-21 20:48:44 UTC	12-MAY-2020 00:00:00 UTC	09-DEC-2024 23:58:50 UTC
6	TOEM_200525OAS_PREDICT__0001.CR.bsp	2020-05-25 14:06:15 UTC	24-MAY-2020 23:58:47 UTC	04-JUL-2020 16:35:22 UTC
7	mar097.2010-2029.bsp	Analysis Time	29-DEC-2009 23:58:53 UTC	01-JAN-2030 23:58:50 UTC
8	mar097.2010-2029.bsp	Analysis Time	29-DEC-2009 23:58:53 UTC	01-JAN-2030 23:58:50 UTC
9	Viking1_200101_210101.boa	Analysis Time	31-DEC-2019 23:58:50 UTC	31-DEC-2020 23:58:50 UTC
10	p_191030-201029-061215_10yr_nominal.nio	Analysis Time	30-OCT-2019 05:28:50 UTC	29-OCT-2020 06:28:50 UTC

Ephemeris files for the bodies analyzed are listed in the table above. Lines for files which have been updated since the last run are colored blue, and each line's body is marked with an "*".

12 References

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13 Acknowledgment

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004).