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Channel Selection Study for Planet-C
and Bepi-Colombo (MMO)

ESA/NASA/JAXA FCM
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JPL

NASA

Bepi Colombo (MMO) Channel Selection Study

BepiColombo will consist of MPO (ESA's) and MMO (JAXA's) two spacecraft. In respect of the relationship between MPO and MMO, these two satellites are linked until the arrival of the Mercury in 2016. Until the separation from MPO, MMO will mainly on ESA's communication link, except the emergency. This frequency selection is based on JAXA's request for MMO part, throughout this presentation, BepiColombo actually refers to JAXA's MMO. BepiColombo prefers to use channel 9 in X-band for its uplink and downlink communications.

In this study, we assume BepiColombo is transmitting starting on the first date (7/23/2012) in the provided trajectory. The trajectory starts around the last apogee before the lunar flyby (the spiraling around the Earth through the radiation belts not included) and ends in the center of Mercury at nominal arrival date.

BepiColombo plans to carry two antennas, one HGA with peak gain of 35 dBi, one MGA with peak gain of 5.4 dBi. The analysis is performed by using HGA.

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BepiColombo's Telecom Parameters

General Info			BepiColombo		
Mission		BepiColombo			
Mission ID		-915			
Mission Start Date		2012 JUL 23 10:49:00.000			
Mission End Date		2018 JAN 01 00:00:00.000			
Trajectory File Name		BepiColombo			
Trajectory Start Date		2012 JUL 23 10:49:00.000			
Trajectory End Date		2018 JAN 01 00:00:00.000			
Uplink			**Uplink Phases**		
Frequency Band		X-Up	1	2	3
Phase No					
Phase Name			HighGainAnts.	MedGainAnts.	
Start Date			2012 JUL 23	2012 JUL 23	
End Date			2018 JAN 01	2018 JAN 01	
Channel Number		9	9	9	
Earth Station Power	dBm	73 (64m), 67 (34m)	73	67	
Earth Station Transmit Antenna Gain	dB	71.5 (64m), 65.5 (34m)	71.5	65.5	
Subcarrier Frequency	kHz	16	16	16	
Subcarrier Type		sine	sine	sine	
Mod Index	Degree	68	68	68	
Uncoded Data Rate	bps	15.625, 1000	1000	15.625	
Symbols Per Bit		1=NRZ	1	1	
Modulation Scheme		PCM/PSK/PM	PCM/PSK/PM	PCM/PSK/PM	
S/C Receive Antenna Gain	dB	35 (HGA), 5.4 (MGA)	35	5.4	
S/C Receive Carrier Noise Bandwidth	Hz	20 - 200	200	200	
S/C Receive Carrier Threshold	dBm				
Downlink			**Downlink Phases**		
Frequency Band		X-Down	1	2	3
Phase No					
Phase Name			HighGainHighDataRate	MedGainLowDataRate	HighGainLowDataRate
Start Date			2012 JUL 23	2012 JUL 23	2012 JUL 23
End Date			2018 JAN 01	2018 JAN 01	2018 JAN 01
Channel Number		9	9	9	9
S/C Power	dBm	43	43	43	43
S/C Transmit Antenna Gain	dB	35 (HGA), 5.4 (MGA)	35	5.4	35
Subcarrier Frequency	kHz	4bps - 512 bps), 65.536 (1024 bps - 819	65.536	8.192	65.536
Subcarrier Type		sqrw	sqrw	sqrw	sqrw
Mod Index	Degree	22.9 - 74.5	60	74.5	60
Coding Method		RS + 7-1/2	RS+7-1/2	RS+7-1/2	RS+7-1/2
Uncoded Data Rate	kbps	.32.64.128.256.512.1024.2048.4096.81	8.192	0.256	1.024
Symbols Per Bit		1=NRZ	1	1	1
Modulation Scheme		PCM(NRZ-L)/PSK/PM	PCM/PSK/PM	PCM/PSK/PM	PCM/PSK/PM
DOR Tones	MHz	yes			
DOR Tone Mod Index	Degree				
Earth Station Receive Antenna Gain	dB	71.5 (64m), 65.5 (34m)	71.5	65.5	65.5

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Assumes BepiColombo starts at 7/23/2012, ends at 12/31/2017, the nearby X-band missions having overlap time frame with BepiColombo are:

1) MTO: NASA's Mars Telesat Orbiter, scheduled to launch in 2009, ends in 2020. Ch. 12 is currently under study for MTO.

2) Planet-C: BepiColombo plans to launch in FY 2011 –2012, while Planet-C, another JAXA's new mission, plans to end in FY 2011. It's unclear to us whether there is any overlap between these two missions. We take precautious approach, assume these two missions are overlapped, BepiColombo's trajectory starts at 7/23/2012, we extended Planet-C's trajectory to 12/31/2012.

3) Mars Odyssey: NASA's mission, scheduled to end in 5/29/2008, but if the mission is very successful, it could be extended beyond the current planed end date.So we extended the mission's trajectory to 12/31/2013.

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BepiColombo (ch. 9) vs. MTO (ch. 12) - Uplink

If BepiColombo's MGA is used during these 4 periods, then there is no uplink interference from MTO to BepiColombo during these periods.
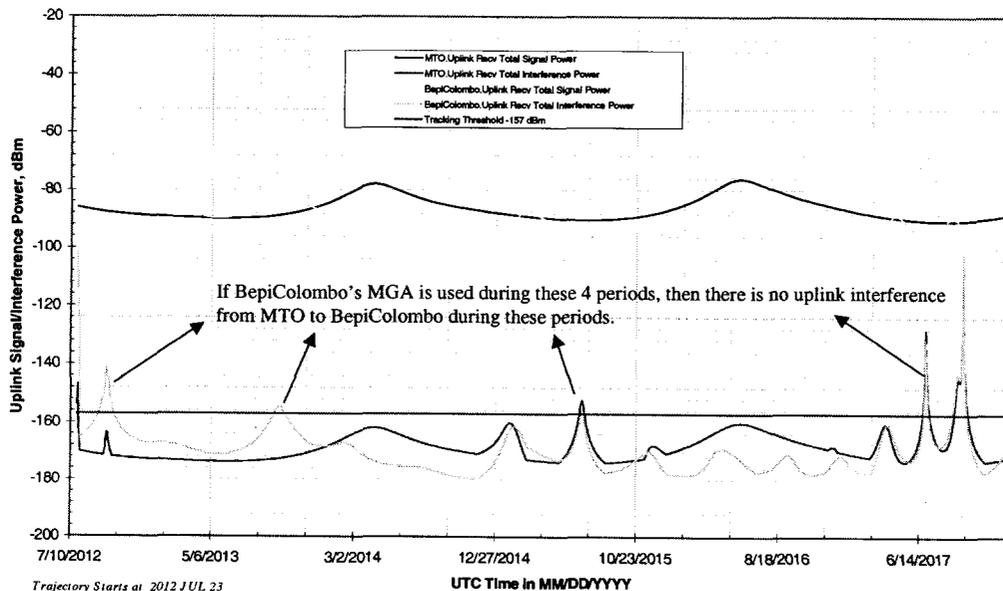
Trajectory Starts at 2012 JUL 23

UTC Time in MM/DD/YYYY

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BepiColombo vs. MTO

BepiColombo (ch. 9) vs. MTO (ch. 12) - Downlink Recv Frequency
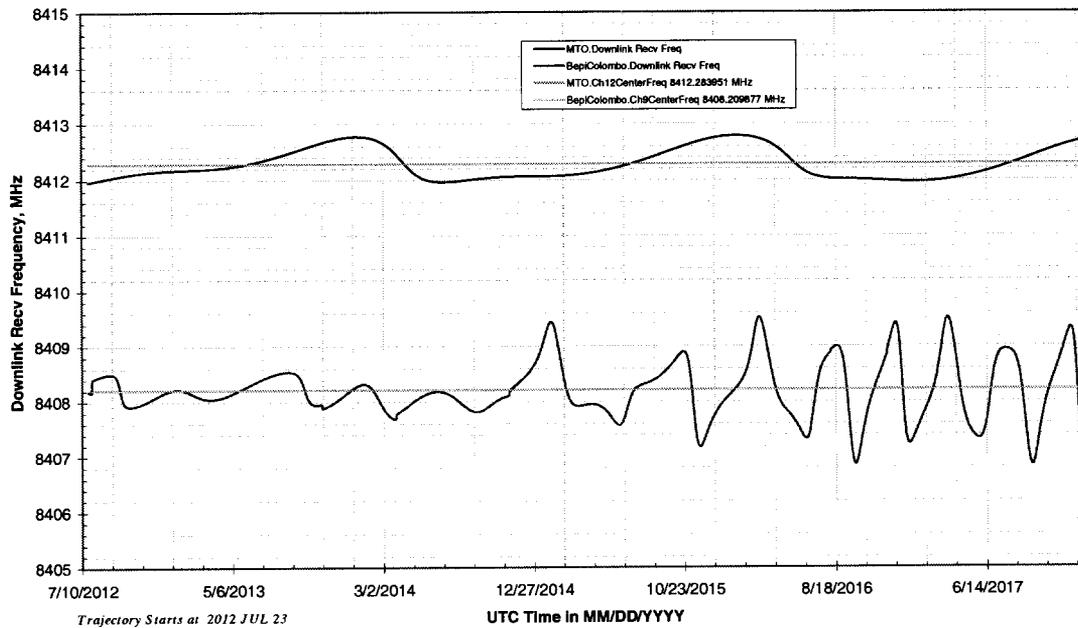
Legend:
- MTO.Downlink Recv Freq
- BepiColombo.Downlink Recv Freq
- MTO.Ch12CenterFreq 8412.283951 MHz
- BepiColombo.Ch9CenterFreq 8408.209877 MHz

Y-axis: Downlink Recv Frequency, MHz
X-axis: UTC Time in MM/DD/YYYY

Trajectory Starts at 2012 JUL 23

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BepiColombo vs. MTO

BepiColombo (ch. 9) vs. MTO (ch. 12) - Downlink

Legend:
- MTO.Downlink Telemetry SIR
- BepiColombo.Downlink Telemetry SIR

Y-axis: Downlink Telemetry Signal to Interference Ratio (SIR), dB
X-axis: UTC Time in MM/DD/YYYY

Trajectory Starts at 2012 JUL 23

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BepiColombo vs. MTO

BepiColombo (ch. 9) vs. MTO (ch.12) Range

Trajectory Starts at 2012 JUL 23

9
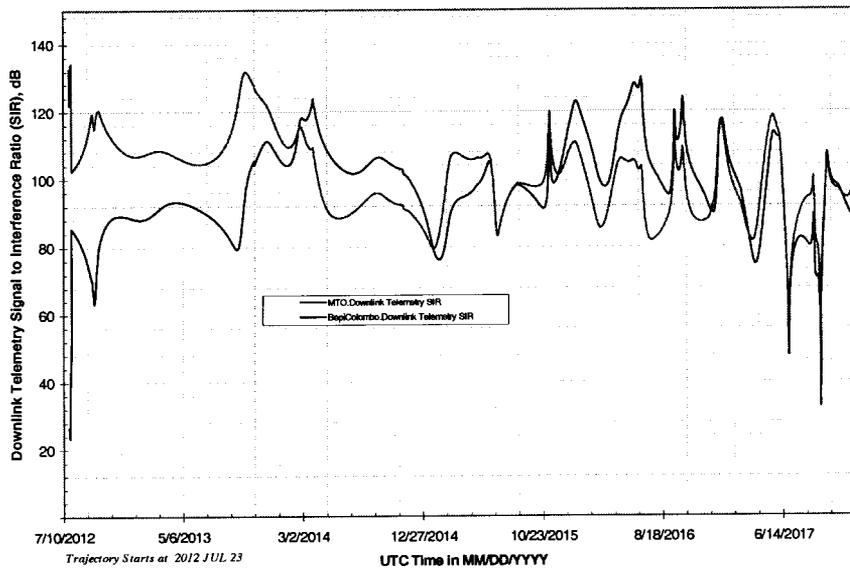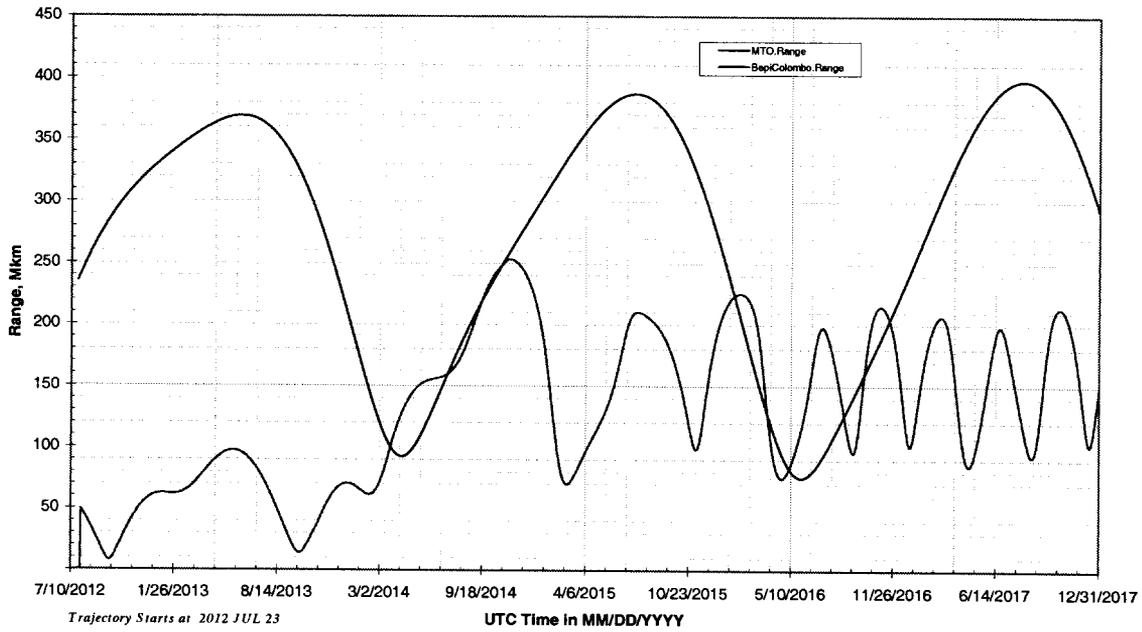
BepiColombo vs. MTO

Angular Separation between BepiColombo and MTO with relative to Earth center

Trajectory Starts at 2012 JUL 23

10
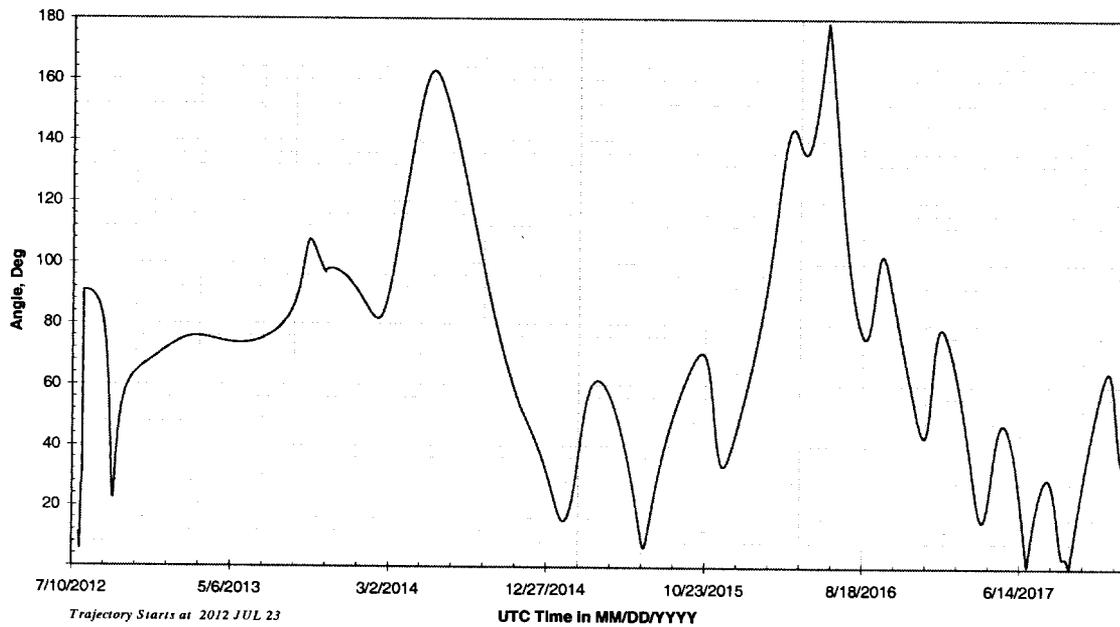
BepiColombo vs. Mars Odyssey

BepiColombo (ch. 9) vs. Mars Odyssey (ch. 8) - Uplink

If BepiColombo uses MGA in these periods, then BepiColombo will receive no uplink interference from Odyssey

Trajectory Starts at 2012 JUL 23
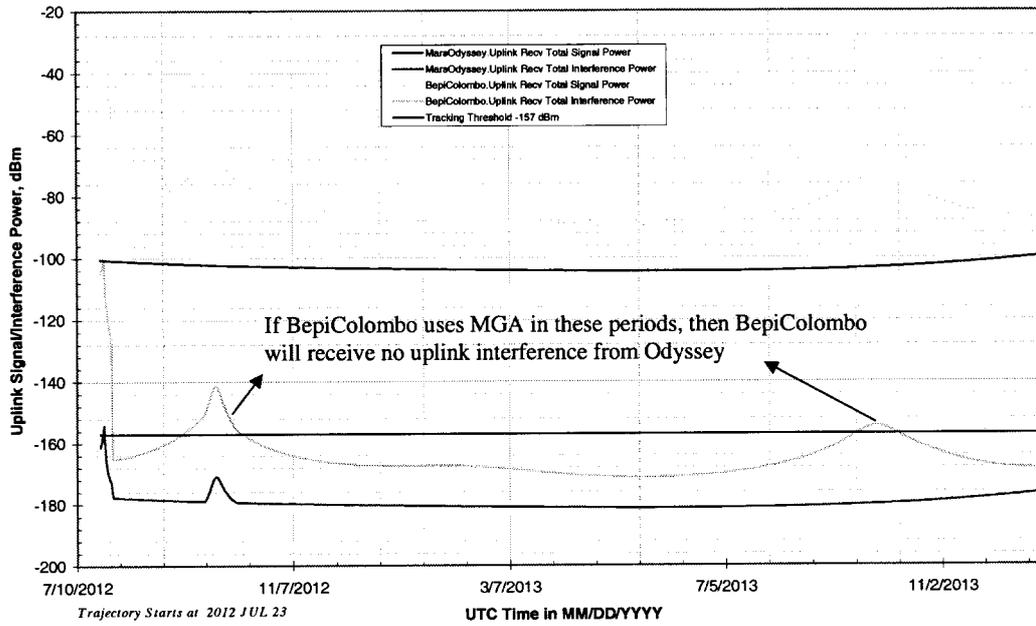
BepiColombo vs. Mars Odyssey

BepiColombo (ch. 9) vs. Mars Odyssey (ch. 8) - Downlink
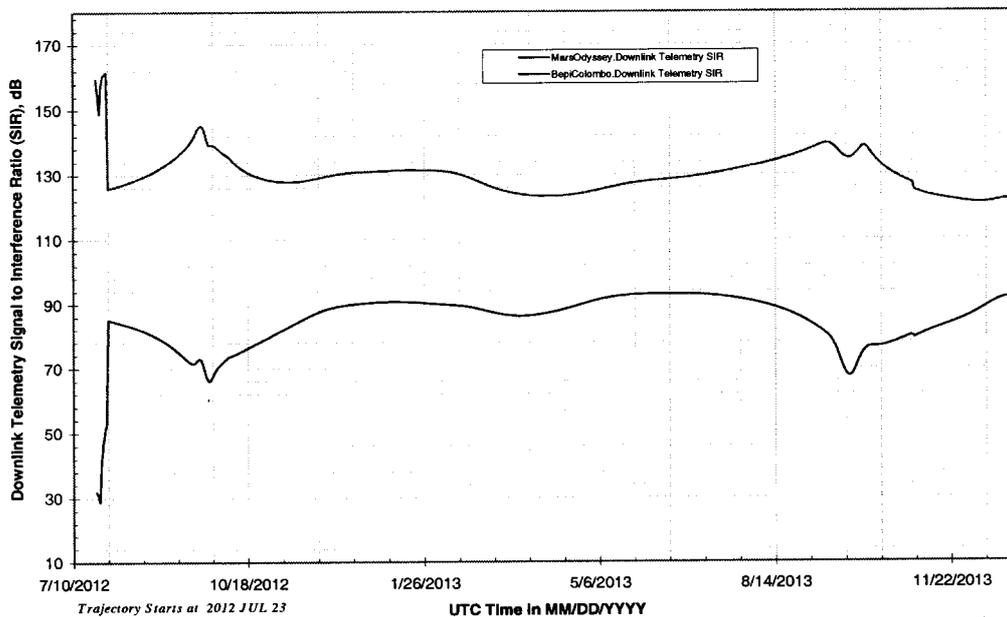
Trajectory Starts at 2012 JUL 23

BepiColombo vs. Mars Odyssey

BepiColombo (ch. 9) vs. Mars Odyssey (ch. 8) - Range

Trajectory Starts at 2012 JUL 23

UTC Time in MM/DD/YYYY

13
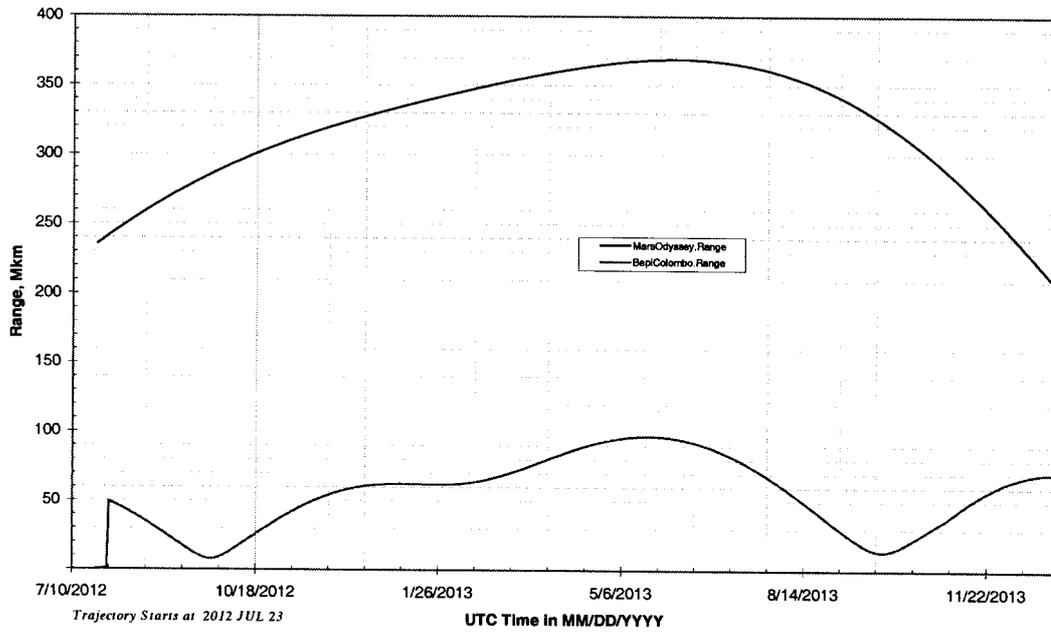
BepiColombo vs. Mars Odyssey

Angular Separation bwtween BepiColombo and Mars Odyssey with relative to Earth center

Trajectory Starts at 2012 JUL 23

UTC Time in MM/DD/YYYY

14
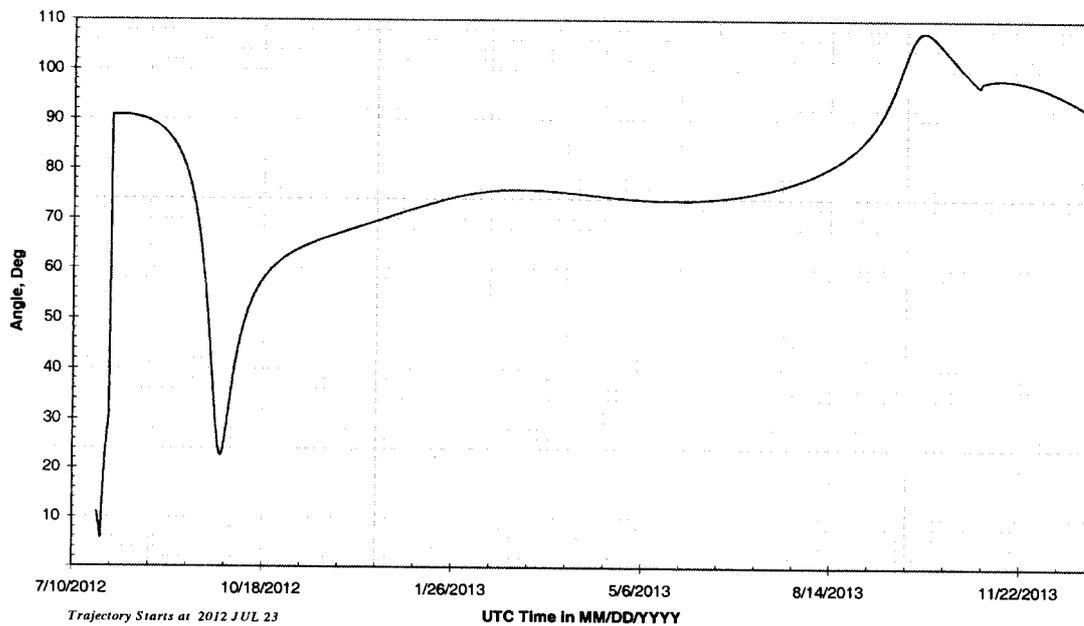
BepiColombo vs. Planet-C

BepiColombo (ch. 9) vs. Planet-C (ch. 9) - Uplink

If BepiColombo uses MGA in this period, then BepiColombo will receive no uplink interference from Planet-C

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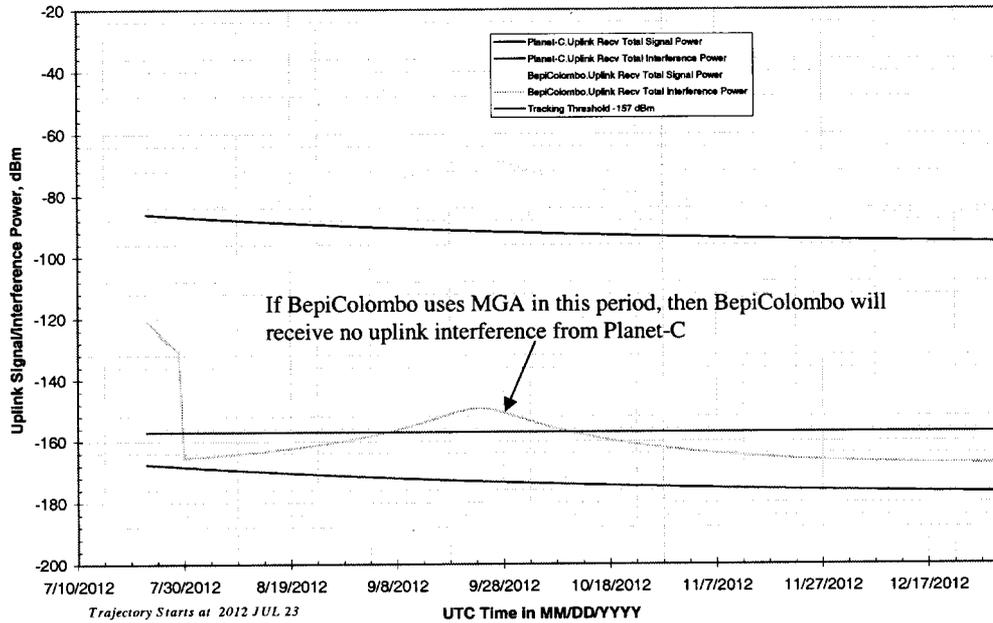
BepiColombo vs. Planet-C

BepiColombo (ch. 9) vs. Planet-C (ch. 9) - Downlink

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BepiColombo vs. Planet-C

BepiColombo(ch. 9) vs. Planet-C (ch. 9) - Range

Trajectory Starts at 2012 JUL 23

UTC Time in MM/DD/YYYY

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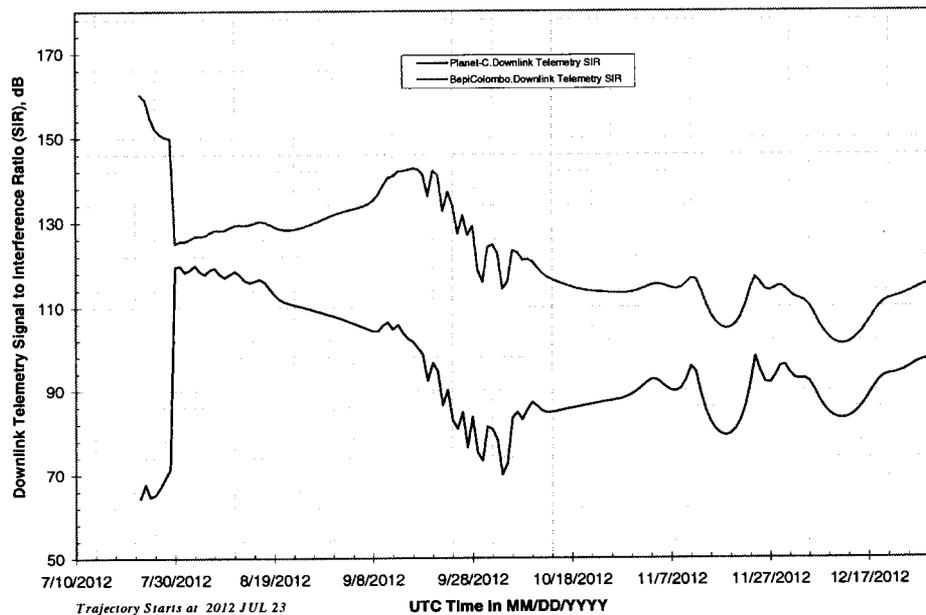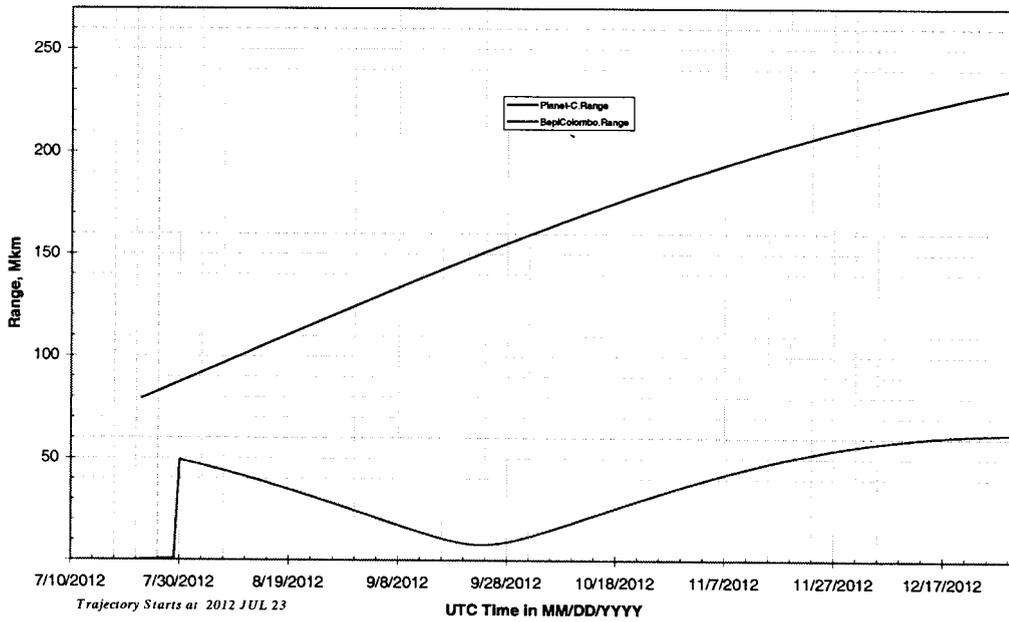
BepiColombo vs. Planet-C

Angular Separation between BepiColombo and Planet-C with relative to Earth Center

Trajectory Starts at 2012 JUL 23

UTC Time in MM/DD/YYYY

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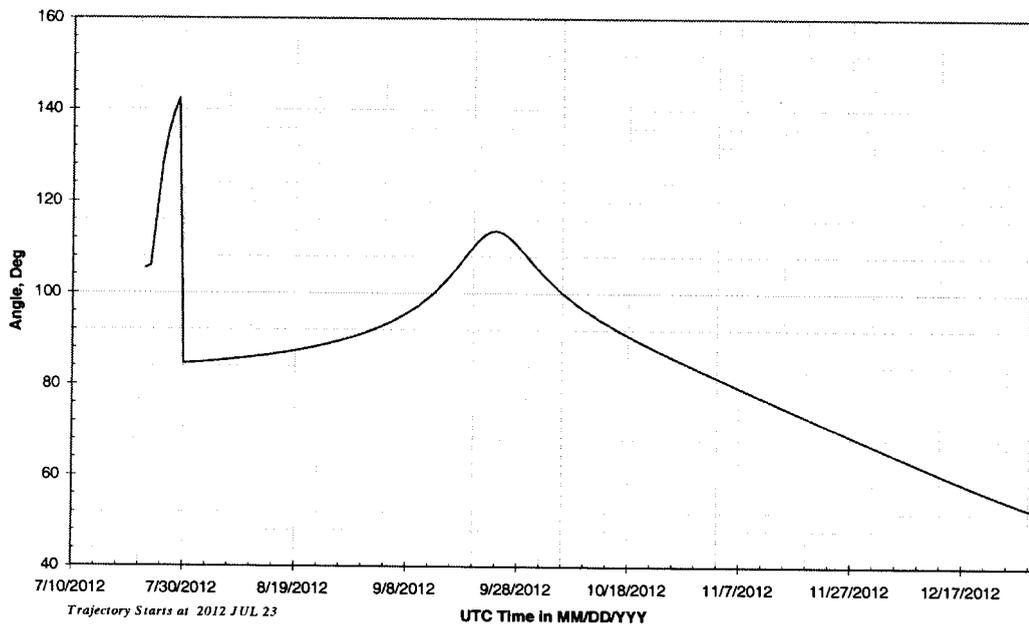
BepiColombo Frequency Selection Study Conclusions

From	To	Link Direction	Mitigation Method
MTO	BepiColombo	Uplink	
MTO	BepiColombo	Uplink	If BepiColombo uses MGA during this period, then there will be no uplink interference.
MTO	BepiColombo	Uplink	If BepiColombo uses MGA during this period, then there will be no uplink interference.
MTO	BepiColombo	Uplink	If BepiColombo uses MGA during this period, then there will be no uplink interference.
MTO	BepiColombo	Uplink	If BepiColombo uses MGA during this period, then there will be no uplink interference.
MTO	BepiColombo	Uplink	If BepiColombo uses MGA during this period, then the uplink interference will be reduced to 9/16/2017 and 9/17/2017 two days only.
BepiColombo	MTO	Uplink	
BepiColombo	MTO	Uplink	
BepiColombo	MTO	Uplink	
Mars Odyssey	BepiColombo	Uplink	
Mars Odyssey	BepiColombo	Uplink	If BepiColombo uses MGA during this period, then there will be no uplink interference.
Mars Odyssey	BepiColombo	Uplink	If BepiColombo uses MGA during this period, then there will be no uplink interference.
Planet-C	BepiColombo	Uplink	If BepiColombo uses MGA during this period, then there will be no uplink interference.

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Planet-C Channel Selection Study

Planet-C Channel Selection Study
Background

- Planet-C launch date: April 30, 2008
- Planet-C O.I. date: Approx. Sep 15, 2009
- Planet-C mission end date: Dec 31, 2011
- Planet-C mission prefers to use X-Band Channel 9
- Planet-C spends about 40 days in an elliptical orbit around Earth
- Analysis performed to the end of the Planet-C mission
- Venus comes in conjunction with Mars several times during the lifetime of Planet-C – many Mars NASA and ESA missions
- Other channel studied: X-Band Channel 24

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Planet-C Channel Selection Study
## Planet-C Telecom Parameters

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JPL   Planet-C Channel Selection Study
Planet-C's Near Earth Phase   **NASA**

- Planet-C's initial elliptical orbit around Earth (approx. 40 days) may cause interference between other deep-space missions (NASA, ESA) in near by channels from DSN sites in Canberra (Australia) and Goldstone (USA).

  Example:
  - Planet-C has line-of-sight with the DSN Canberra site with azimuth angles in the north direction towards the Ecliptic Plane:

Planet C Mutual Visibility with USC34m (Japan) and Canberra (Australia)
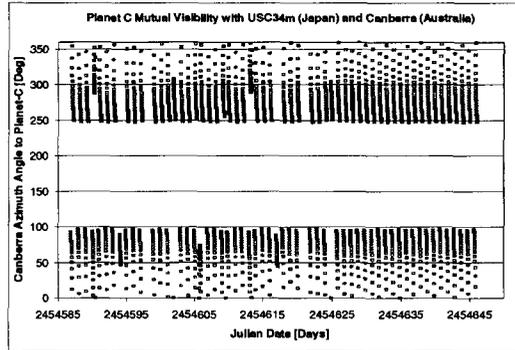
- Possible uplink interference to Planet-C and downlink interference to missions using nearby channels
- Coordination necessary during this period

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JPL   Planet-C Channel Selection Study
Planet-C Channel 9   **NASA**

- Nearby X-band Missions
  - Mars Odyssey (8) uplink and downlink (End of mission: May 29, 2008)
  - Ulysses (9) downlink only (End of mission: Sep 30, 2004)
  - Nozomi (11) downlink only (End of mission: Dec 31, 2005)
  - Mar Telesat Orbiter (12) uplink and downlink (Launch: Oct 4, 2009; end of mission: Aug 29, 2020)

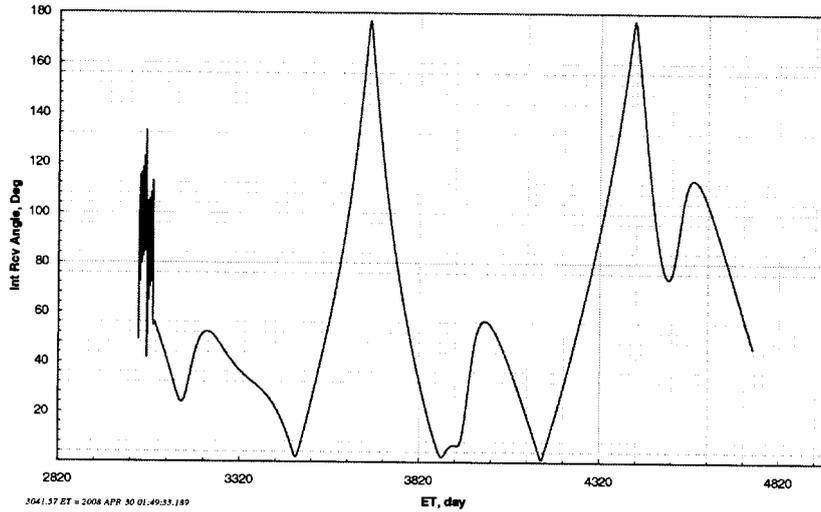- Possible interference scenarios with Mars Odyssey and Mars Telesat (MTO)

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Planet-C@9{EARTH}_MarsOdyssey@8{EARTH(2)} Int Rcv Angle

Assuming the Mars Odyssey mission is extended to the end of the Planet-C mission.

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Planet-C@9{EARTH}_MarsOdyssey@8{EARTH(2)} D_Drlr

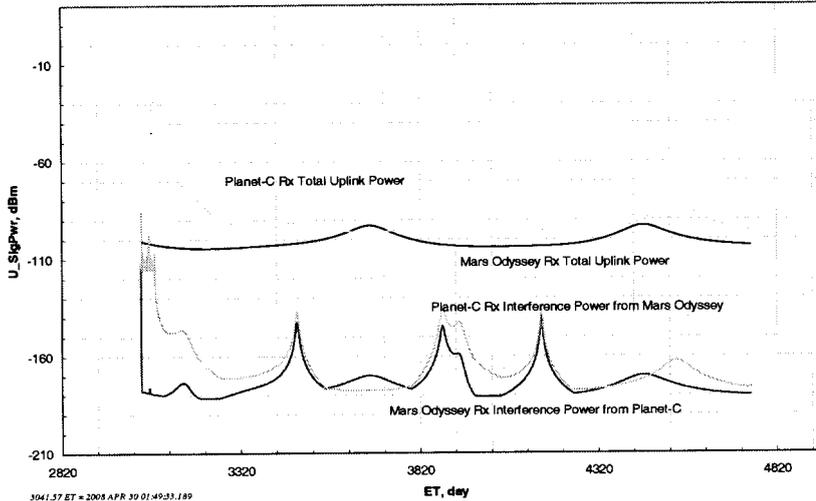

Assuming the Mars Odyssey mission is extended to the end of the Planet-C mission.
D_Drlr = Downlink telemetry signal-to-interference ratio (SIR)

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JPL Planet-C Channel Selection Study – Channel 9
Total Uplink Power for Planet-C and Mars Odyssey

Planet-C@9{EARTH}_MarsOdyssey@8{EARTH(2)} U_SigPwr & U_IntPwr



3041.57 ET = 2008 APR 30 01:49:33.189

- Assuming the Mars Odyssey mission is extended to the end of the Planet-C mission.
- Figure generated assuming HGA is used by Planet-C. If LGA is used, Planet-C's received and interference power will be 37 dB lower.

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JPL Planet-C Channel Selection Study – Channel 9
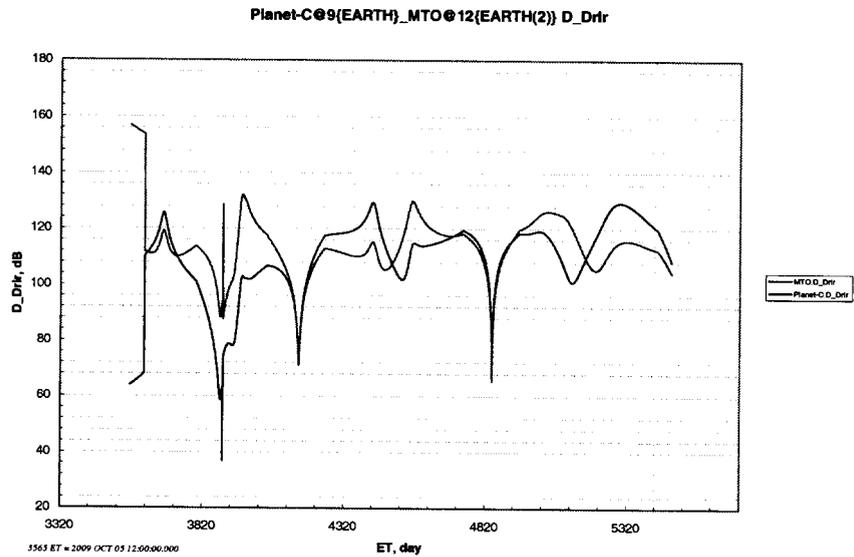## Angular separation between Planet-C and MTO

Planet-C@9{EARTH}_MTO@12{EARTH(2)} Int Rcv Angle
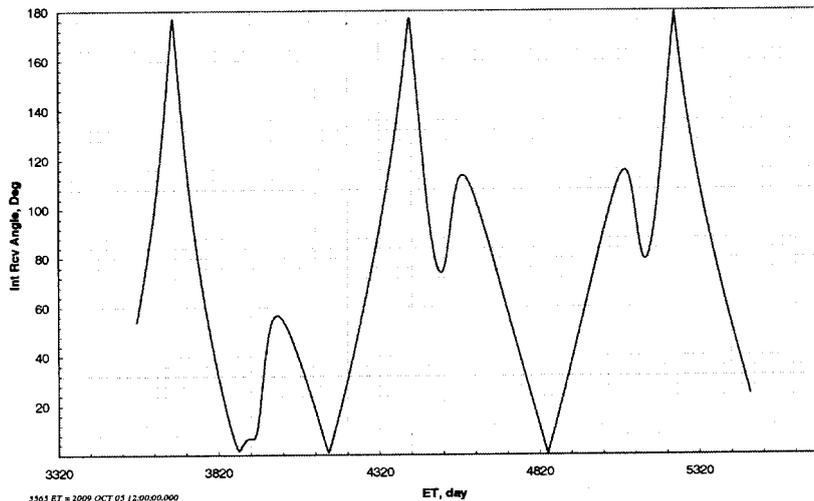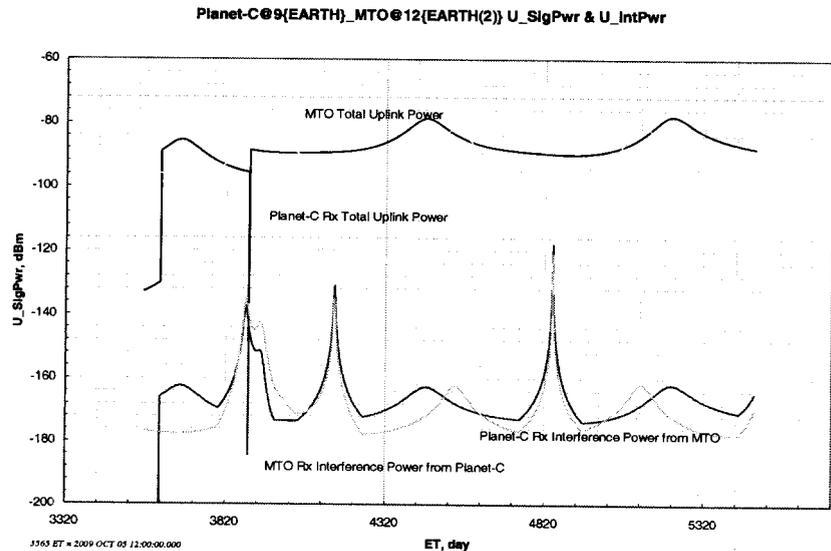

3563 ET = 2009 OCT 05 12:00:00.000

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Planet-C Channel Selection Study – Channel 9 Downlink (Telemetry) SIR (Signal-to-Interference Ratio) between Planet-C and MTO

Planet-C@9{EARTH}_MTO@12{EARTH(2)} D_Drlr

Planet-C Channel Selection Study – Channel 9 Total Uplink Power for Planet-C and MTO

Planet-C@9{EARTH}_MTO@12{EARTH(2)} U_SigPwr & U_IntPwr

- Figure generated assuming HGA is used by Planet-C. If LGA is used, Planet-C's received and interference power will be 37 dB lower.
- MTO and Planet-C will be three channels away. That translates to about an additional 30 dB ranging tone attenuation.

JPL Planet-C Channel Selection Study – Channel 9 NASA
Potential Interference Scenarios

- If Channel 9 is selected for Planet-C, no mutual interference with MTO (12). Possible downlink interference to Mars Odyssey (8) and uplink interference to Planet-C until the end of Mars Odyssey mission on May 29, 2008 when Planet-C is still in its elliptical orbit around Earth[1].

Potential Interference Period	Interference From	Victim	Link Affected
Apr 30, 2008 to May 29, 2008	Planet-C	Mars Odyssey	Downlink
Apr 30, 2008 to May 29, 2008[2]	Mars Odyssey	Planet-C	Uplink

- If Mars Odyssey extends its mission to the end Planet-C:

Potential Interference Period	Interference From	Victim	Link Affected
Apr 30, 2008 to Jun 8, 2008	Planet-C	Mars Odyssey	Downlink
Jun 26, 2009 to Jul 20, 2009	Planet-C	Mars Odyssey	Uplink
Aug 5, 2010 to Sep 7, 2010	Planet-C	Mars Odyssey	Uplink
May 12, 2011 to Jun 3, 2011	Planet-C	Mars Odyssey	Uplink
Apr 30, 2008 to Sep 26, 2008[2]	Mars Odyssey	Planet-C	Uplink
Jun 16, 2009 to Jul 27, 2009	Mars Odyssey	Planet-C	Uplink
Jul 24, 2010 to Nov 21, 2010	Mars Odyssey	Planet-C	Uplink
May 7, 2011 to Jun 7, 2011	Mars Odyssey	Planet-C	Uplink

[1] In our analysis, if the downlink telemetry signal-to-interference ratio (SIR) is above 20 dB, the link is considered acceptable. If the uplink interference power in adjacent channels is less than -157 dBm, the link is considered acceptable.
[2] Analysis performed assuming Planet-C using HGA, if LGA is used the potential interference period is reduced to Apr 30, 2008 to Jun 8, 2008.

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JPL
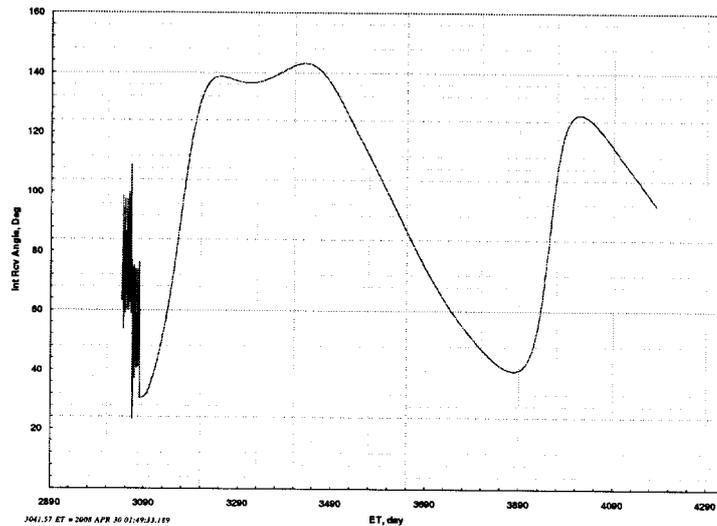# Planet-C Channel Selection Study – Planet-C Channel NASA

- Due to Mars-Venus conjunctions which occur several times during Planet-C's lifetime and the number of Mars missions, Planet-C should use a frequency channel not adjacent to Mars missions.
- Channel 24 is selected for study
- Nearby X-band Missions
  - Kepler (21) uplink and downlink (End of mission: Jul 31, 2011)
  - Cassini (23) downlink only (End of mission: Jun 30, 2010)
  - Stardust (23) downlink only (End of mission: Jan 14, 2006)
  - Cassini (25) uplink and downlink (End of mission: Jun 30, 2010)
  - Stardust (25) uplink and downlink (End of mission: Jan 14, 2006)
  - Messenger (27) uplink and downlink (End of mission: Apr 6, 2010)
- Possible interference scenarios with Kepler, Cassini, and Messenger

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Planet-C Channel Selection Study – Channel 24
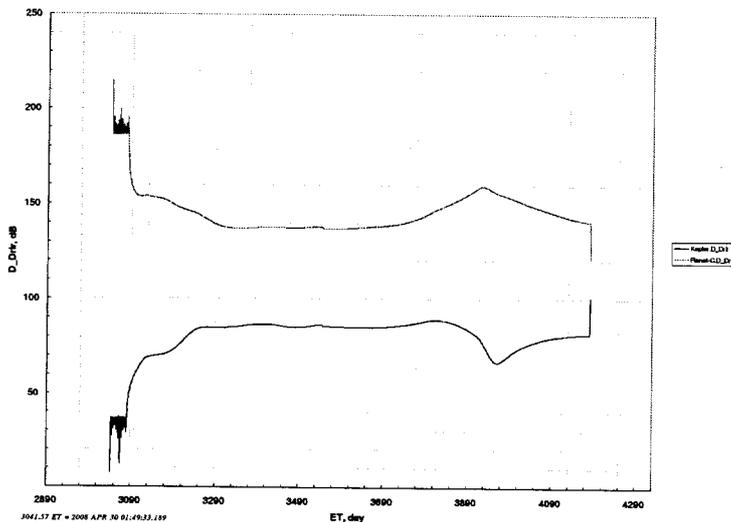## Angular separation between Planet-C and Kepler

Planet-C@24{EARTH}_Kepler@21{EARTH(2)} Int Rcv Angle

3041.57 ET = 2008 APR 30 01:49:33.189

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Planet-C Channel Selection Study – Channel 24
Downlink (Telemetry) SIR (Signal-to-Interference Ratio) between Planet-C and Kepler

Planet-C@24{EARTH}_Kepler@21{EARTH(2)} D_Drlr

3041.57 ET = 2008 APR 30 01:49:33.189

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JPL Planet-C Channel Selection Study – Channel 24 **NASA**
Total Uplink Power for Planet-C and Kepler

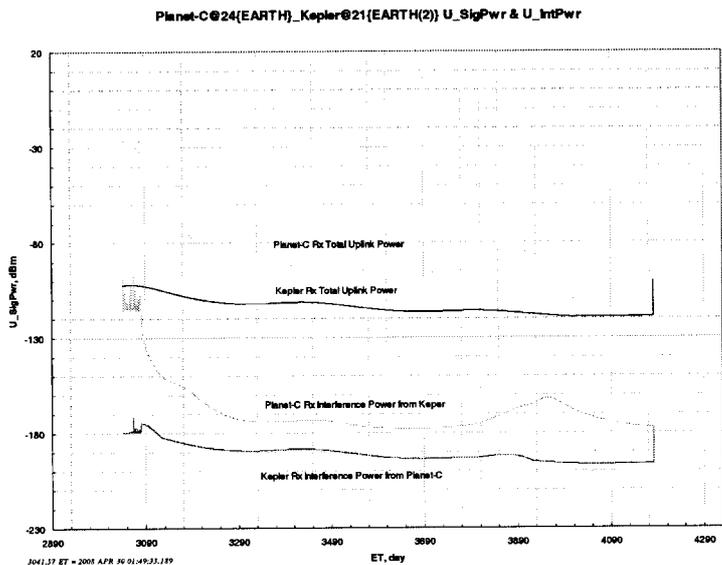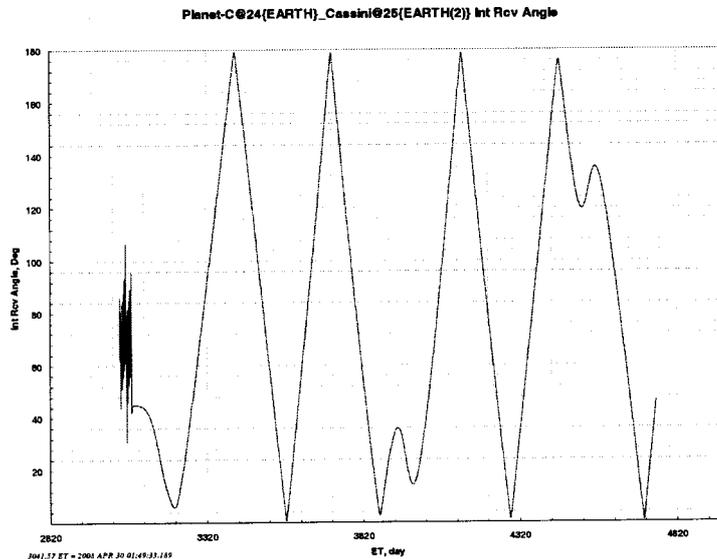Planet-C@24{EARTH}_Kepler@21{EARTH(2)} U_SigPwr & U_IntPwr

Figure generated assuming HGA is used by Planet-C. If LGA is used, Planet-C's received
and interference power will be 37 dB lower.

JPL Planet-C Channel Selection Study – Channel 24 **NASA**
Angular separation between Planet-C and Cassini (23,25)
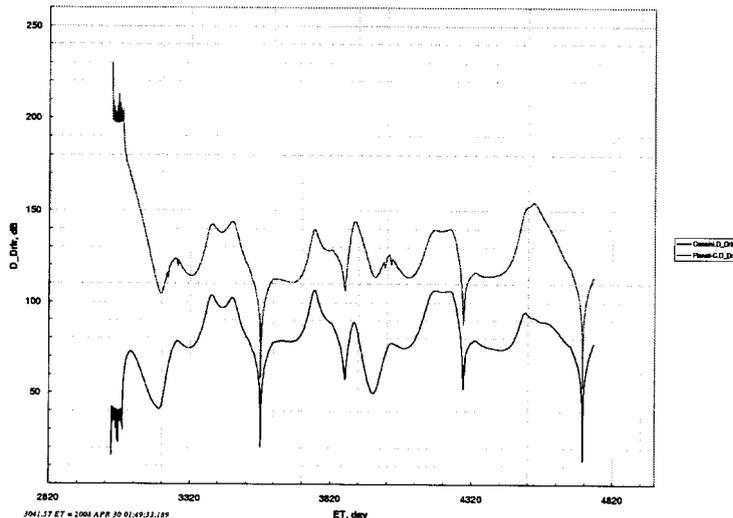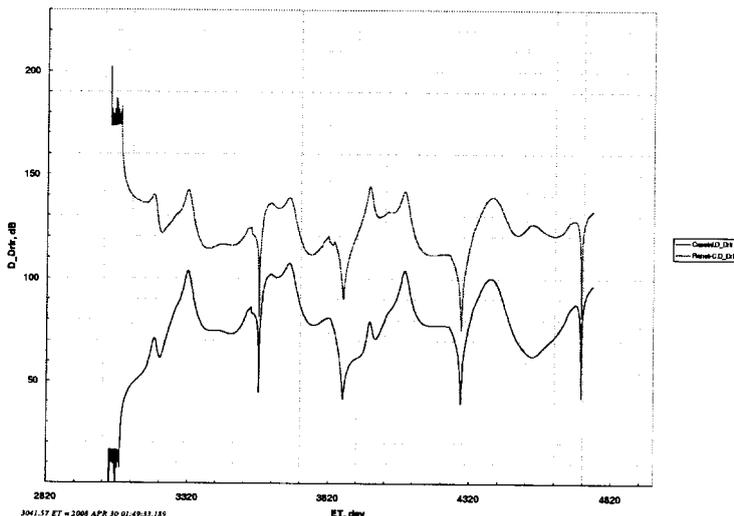
Planet-C@24{EARTH}_Cassini@25{EARTH(2)} Int Rcv Angle

Assuming the Cassini mission is extended to the end of the Planet-C mission.

Planet-C Channel Selection Study – Channel 24 Downlink (Telemetry) SIR (Signal-to-Interference Ratio) between Planet-C and Cassini (23)

Assuming the Cassini mission is extended to the end of the Planet-C mission.

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Planet-C Channel Selection Study – Channel 24 Downlink (Telemetry) SIR (Signal-to-Interference Ratio) between Planet-C and Cassini (25)

Assuming the Cassini mission is extended to the end of the Planet-C mission.

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Total Uplink Power for Planet-C and Cassini (25)
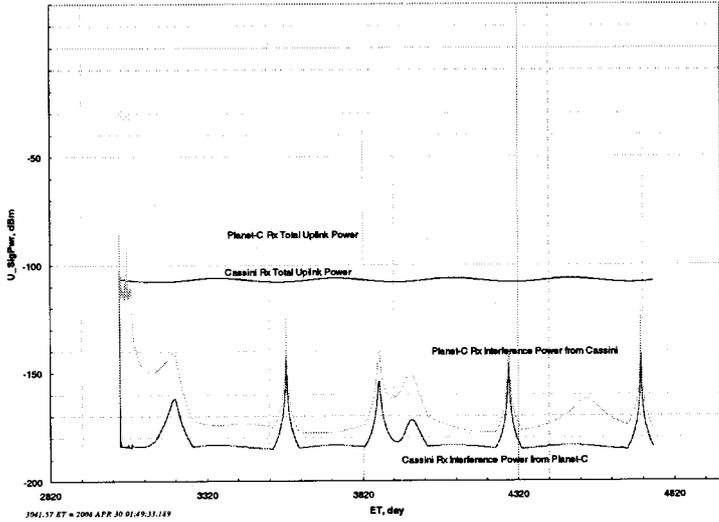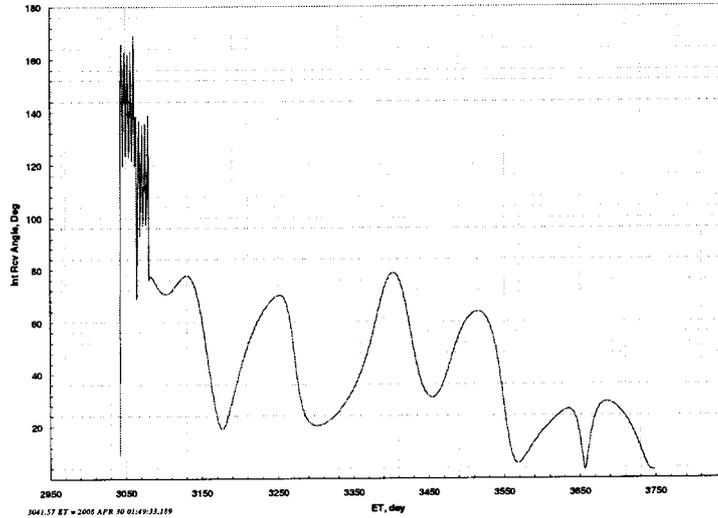
Planet-C@24{EARTH}_Cassini@25{EARTH(2)} U_SigPwr & U_IntPwr

Figure generated assuming HGA is used by Planet-C. If LGA is used, Planet-C's received and interference power will be 37 dB lower.

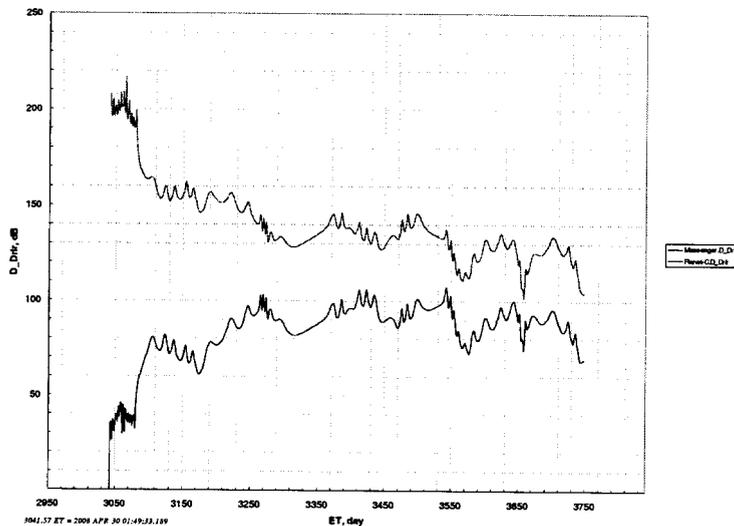# Angular separation between Planet-C and Messenger

Planet-C@24{EARTH}_Messenger@27{EARTH(2)} Int Rcv Angle

Planet-C Channel Selection Study – Channel 24
Downlink (Telemetry) SIR (Signal-to-Interference Ratio) between Planet-C and Messenger

Planet-C@24{EARTH}_Messenger@27{EARTH(2)} D_Drlr

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Planet-C Channel Selection Study – Channel 24
Total Uplink Power for Planet-C and Messenger

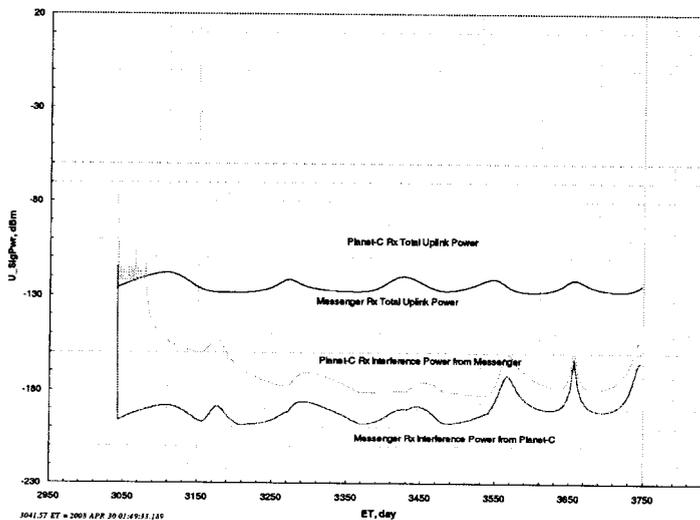Planet-C@24{EARTH}_Messenger@27{EARTH(2)} U_SigPwr & U_IntPwr

Figure generated assuming HGA is used by Planet-C. If LGA is used, Planet-C's received and interference power will be 37 dB lower.

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Potential Interference Scenarios

- In the near-Earth phase of the Planet-C mission, including the period spent in the elliptical orbit, the Planet-C uplink can be interfered and the downlinks of nearby channels can be interfered[1]. The rest of the interference scenarios occur at uplinks due to conjunctions:

Potential Interference Period	Interference From	Victim	Link Affected
Apr 30, 2008 to Jun 8, 2008	Planet-C	Kepler	Downlink
Apr 30, 2008 to Jun 8, 2008	Planet-C	Cassini (23)	Downlink
Apr 30, 2008 to Jun 8, 2008	Planet-C	Cassini (25)	Downlink
Apr 30, 2008 to Jun 8, 2008	Planet-C	Messenger	Downlink
Oct 10, 2009 to Oct 16, 2009	Planet-C	Cassini (25)	Uplink
Aug 6, 2010 to Aug 11, 2010	Planet-C	Cassini (25)	Uplink
Sep 27, 2011 to Oct 2, 2011	Planet-C	Cassini (25)	Uplink
Apr 30, 2008 to Nov 14, 2008[2]	Cassini (25)	Planet-C	Uplink
Oct 7, 2009 to Oct 20, 2009	Cassini (25)	Planet-C	Uplink
Jul 28, 2010 to Aug 25, 2010	Cassini (25)	Planet-C	Uplink
Oct 23, 2010 to Dec 10, 2010	Cassini (25)	Planet-C	Uplink
Sep 25, 2011 to Oct 6, 2011	Cassini (25)	Planet-C	Uplink

[1] In our analysis, if the downlink telemetry signal-to-interference ratio (SIR) is above 20 dB, the link is considered acceptable. If the uplink interference power in adjacent channels is less than -157 dBm, the link is considered acceptable.

[2] Analysis performed assuming Planet-C using HGA, if LGA is used the potential interference period is reduced to Apr 30, 2008 to Jun 8, 2008.

- In the near-Earth phase of the Planet-C mission, including the period spent in the elliptical orbit, the Planet-C uplink can be interfered and the downlinks of nearby channels can be interfered regardless of which channel Planet-C uses.
- Either Channel 9 or Channel 24 is suitable for Planet-C. With the exception of the near-Earth phase of the Planet-C mission, all potential interference scenarios are for uplinks.