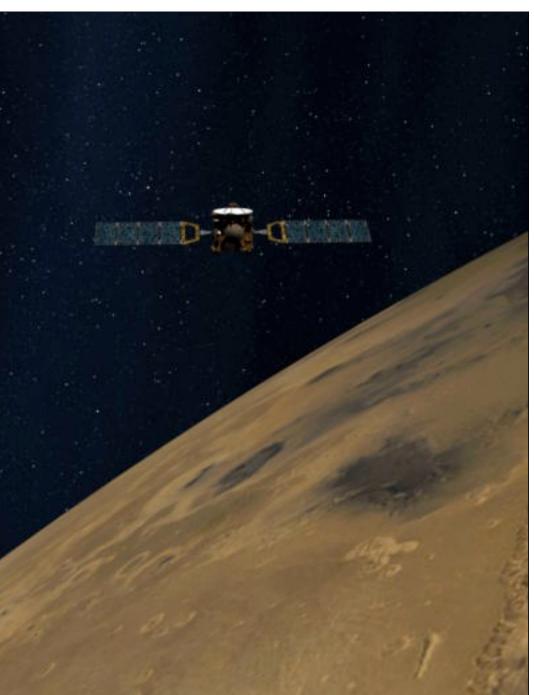
Mars Express science planning and operations and their accuracy

R. Pischel, H. Hoffmann, T. Roatsch,V. Companys, M. Lauer, T. Zegers,M. Ricketts









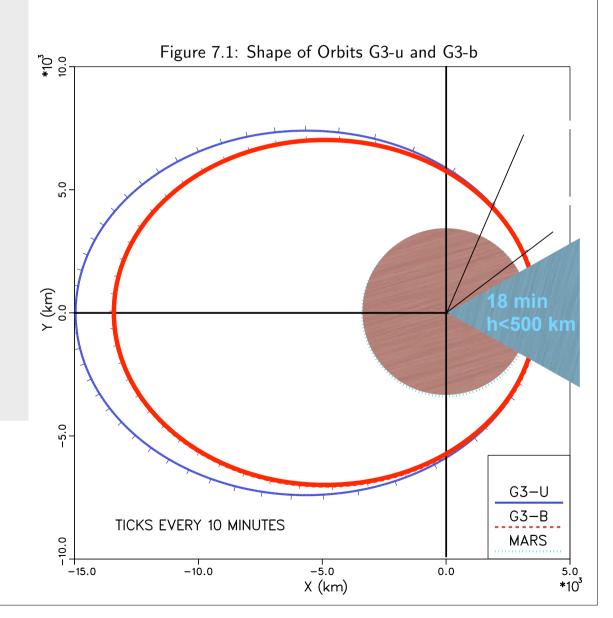
Contents

Basic MEX operations parameters MEX Instrument requests

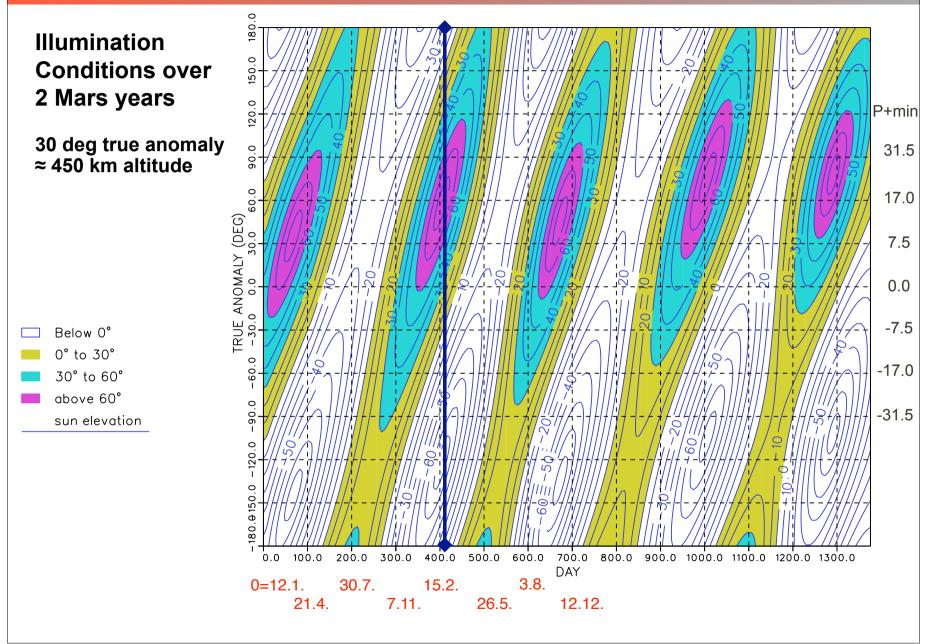
Science planning Outlook: Extended mission

Basic MEX operations parameters: Orbit

- Around Mars
 - highly elliptical, polar
 - period 6.75 h
 - 3:11 ground track resonance
 - 2.5 x latitude coverage
 - full seasonal coverage
- Mars/MEX Earth Sun
 - day/night observations
 60% day, 40% night
 - data rate (for 35m)
 0.8 to 5.2 Gb @ 8h/day
 - power 500 to 730W
 - long eclipses:3 phases max. 90 min



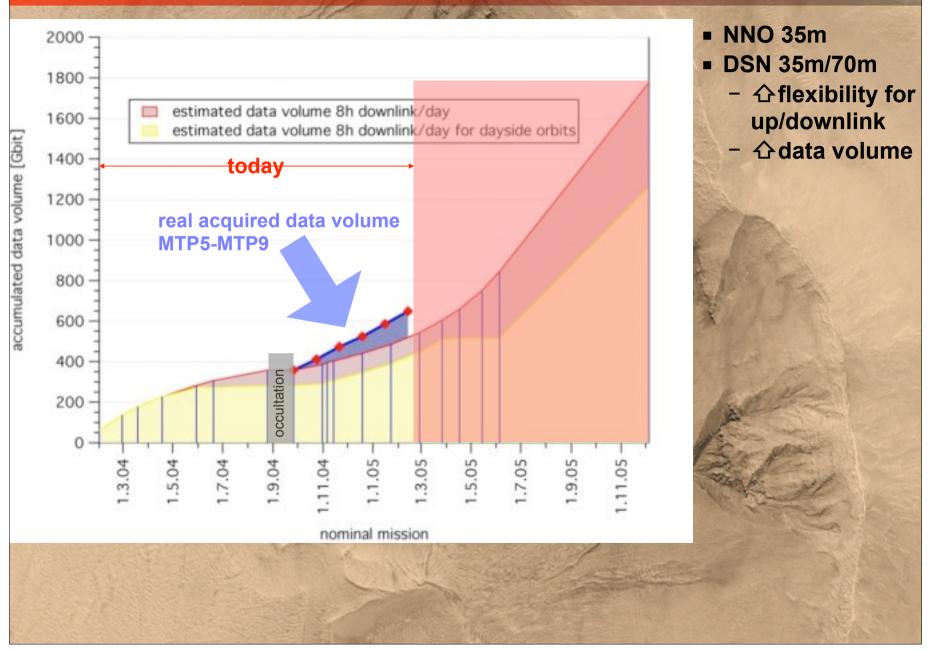
Basic MEX operations parameters: Sharing of day/night



Basic MEX operations parameters: S/C and mission design

- S/C
 - 3-axis stabilized, slews <0.15 deg/s</p>
 - for normal conditions (eclipses < 40 min): 1x nadir +1x inertial ptg per orbit
 - however, restrictions due 70% power problem for eclipses > 40 min
 - downlink: nearly 24/7 coverage NNO (35 m) + DSN
 - up/downlink: 1x 4h contiguous link/day + (4+X)h/day
- Mission
 - nominal mission: 1 Mars year=2440 orbits, 706 mission days
 - no 2 orbits cover the same surface point under the same conditions (illumination, time distance from pericenter, distances to Earth and Sun)

MEX downlink

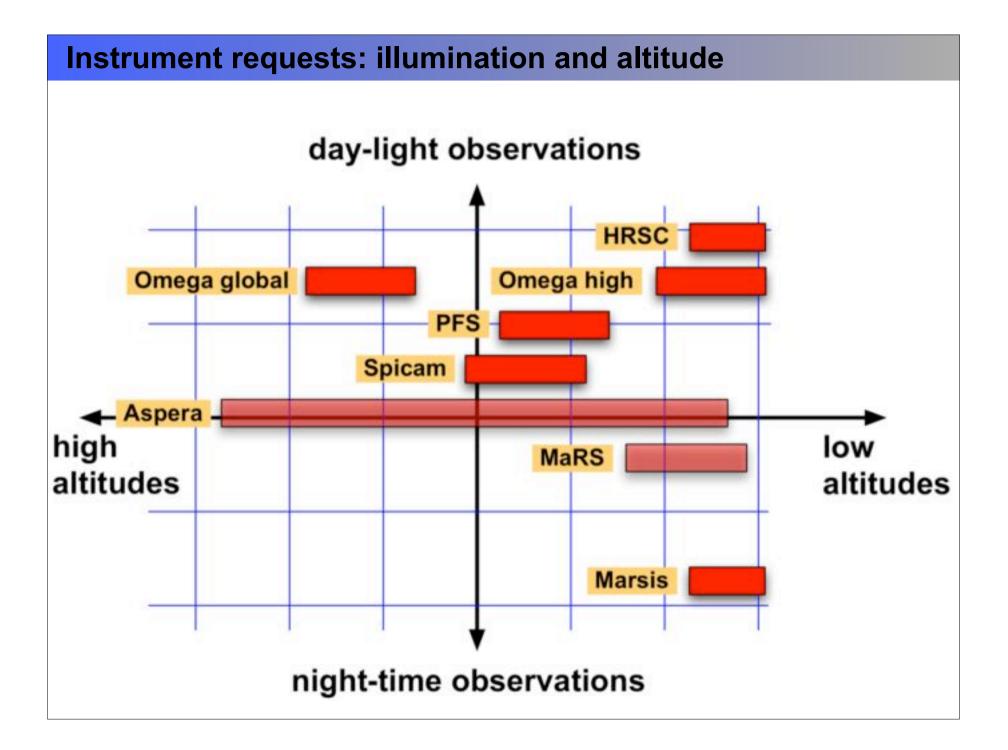


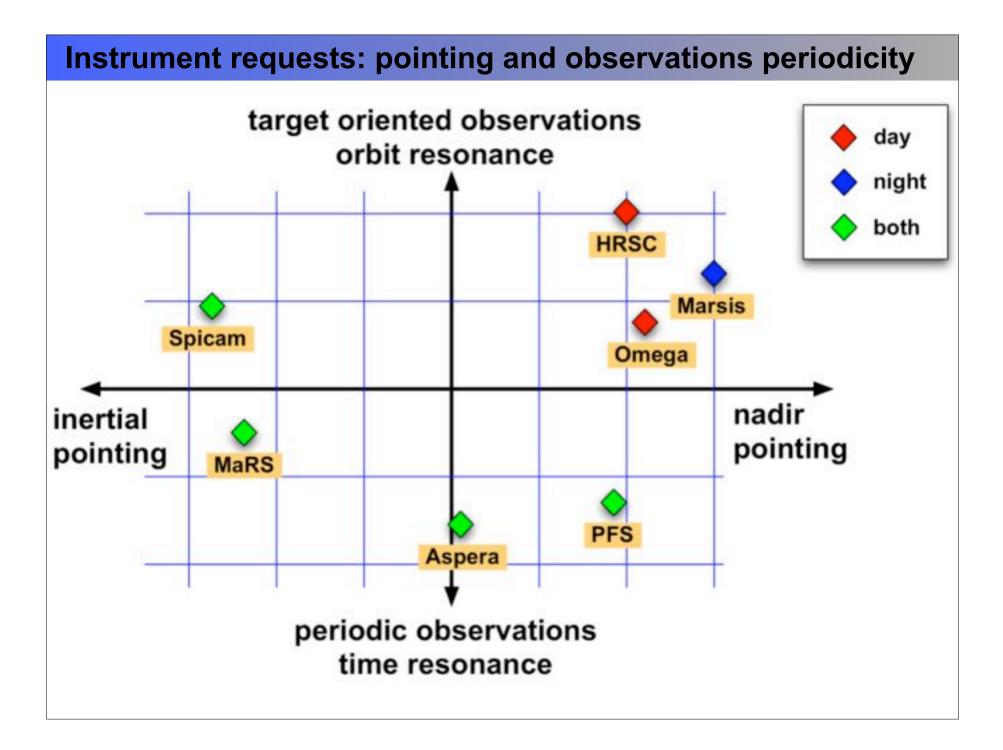
Instrument operation requests

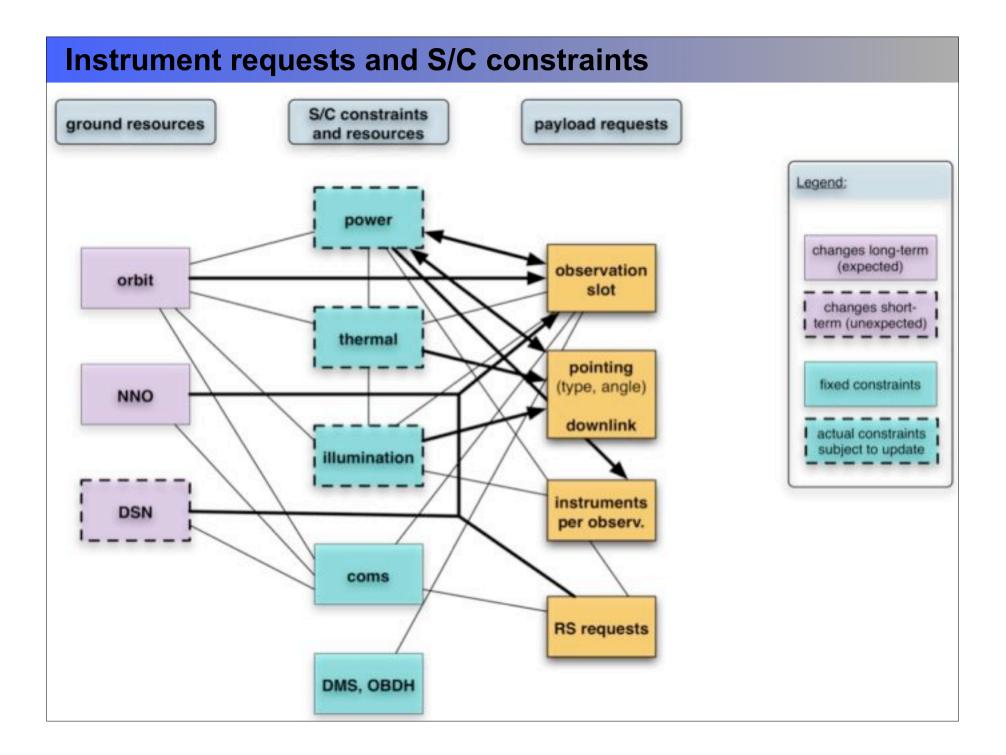
- Instrument objectives lead to highly diverse operation requests with respect to:
 - type, position and duration of science pointings
 - periodicity of observations

Sharing of resources:

- near pericenter prime time
- number and type of science pointings
- downlink volume, memory capacity
- on-board bus data rate







Science planning: constraints

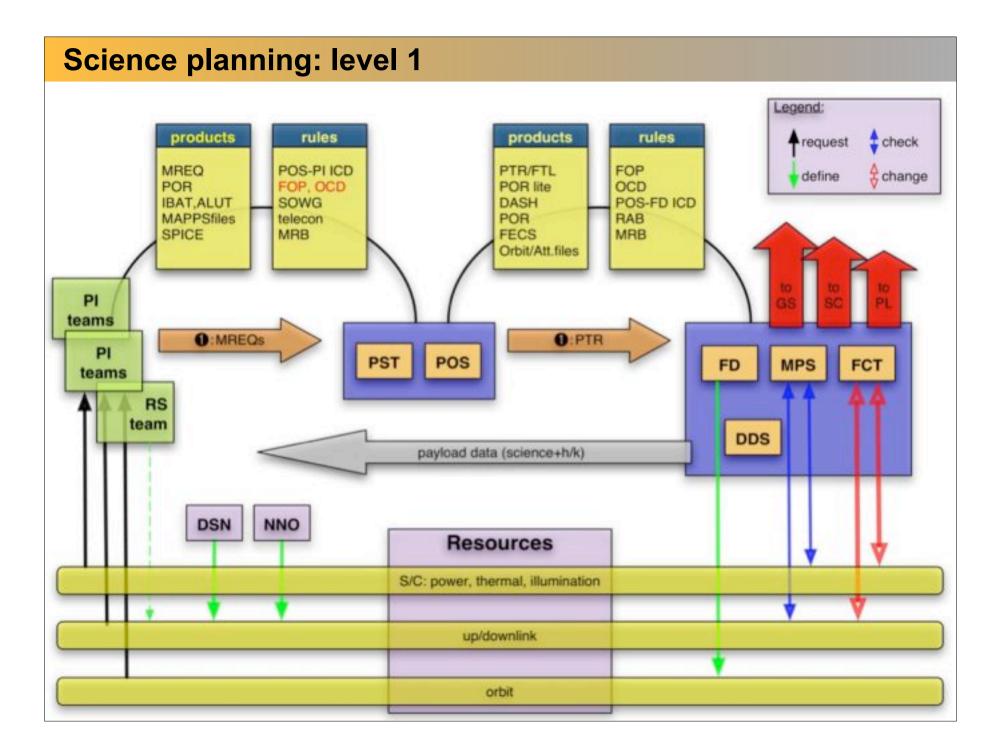
- objective
 - fulfill mission science goals
 - optimum use of resources
- science objectives
- illum., power etc. constraints
- ➡ science themes
- ➡ science master plan

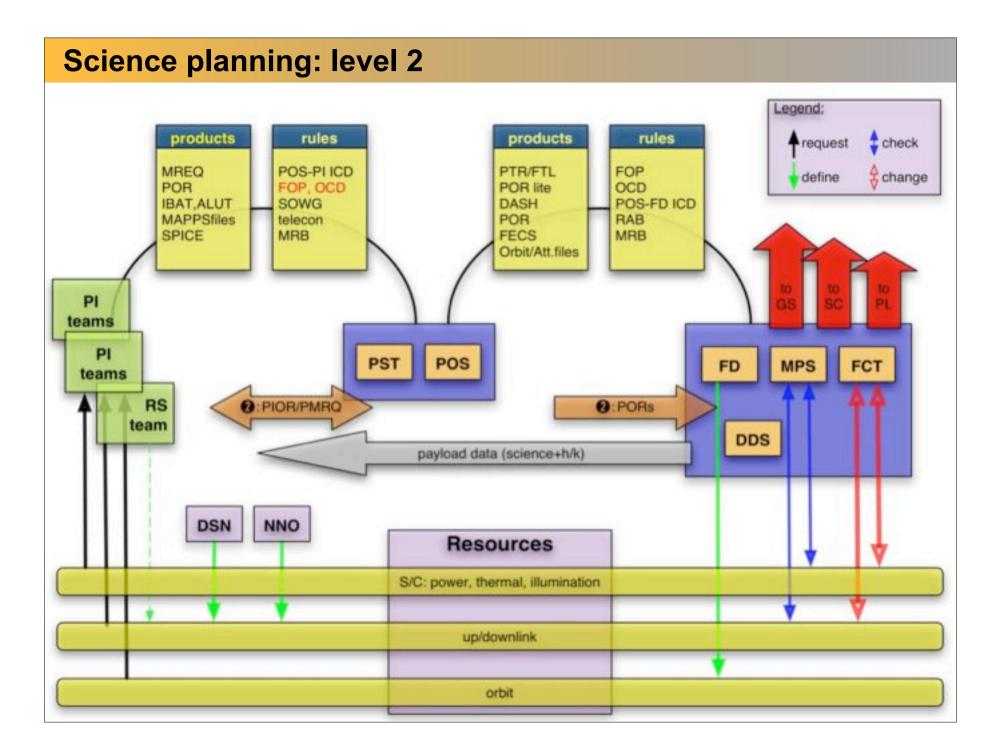
priorities per planning period

- spacecraft
 - mid-term planning for 1 month with 2 months lead time
 - highly accurate orbit maintenance (optimized reaction wheel off-loading)
 - highly accurate science pointings
 - validation of power/thermal models during routine phase
- ground stations
 - coordination with other planetary missions
 - updates of availability schedule may lead to late changes of a major resource

Science planning: 2 level process

- mid-term planning level 1: step 1
 - agreement of instrument plans using instrument mode level requests (MREQs)
 - result: pointing request file, instrument on/off times, data share plan
 - duration: 2-3 weeks
 - covered period: 4 weeks
- mid-term planning level 1: step 2
 - check/verification of requests
 - generation of S/C and ground station commands
 - duration: 4 weeks (1 iteration step)
- planning level 2: step 1
 - generation of instrument command files (PORs) 4x 1 week
 - based on instrument mode level request (MREQs)
- planning level 2: step 2
 - check+merge of instrument commands with S/C and groundstation

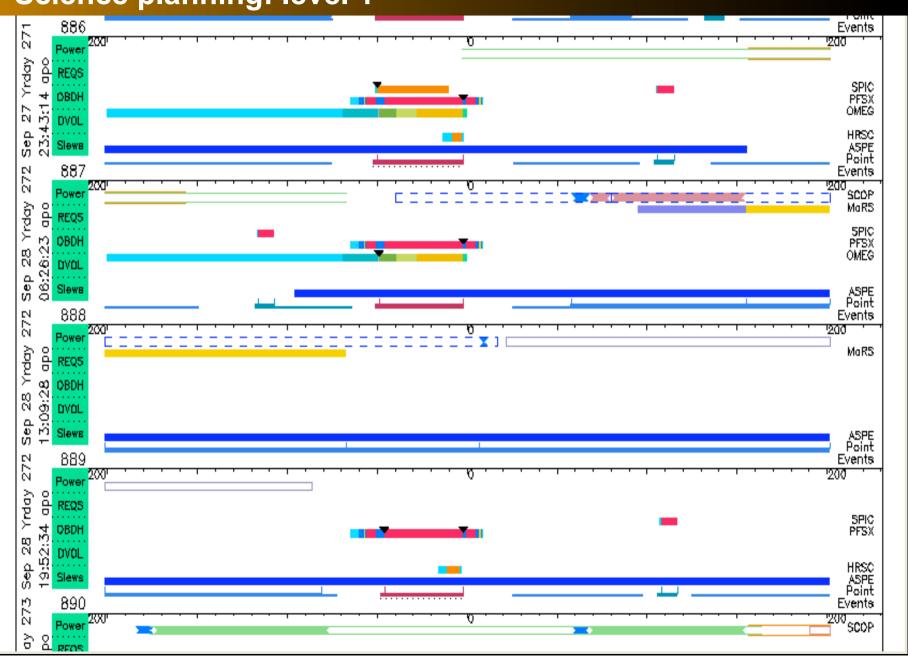




Science planning schedule

| | | | | | Apr05 |
|-----------------------------------|----------|---------|------|--|---|
| Activity Name | Start | Finish | Dur. | SSVITATFSS | NTFSSVITNTFSSVITN 13141516171819221223425227 |
| MTP08: orbits 1186-1285 | 20.12.04 | 17.1.05 | 28 | | |
| MTP09: orbits 1286-1383 | 17.1.05 | 14.2.05 | 28 | | |
| MTP10: orbits 1384-1482 | 14.2.05 | 14.3.05 | 28 | | |
| MTP11: orbits 1483-1584 | 14.3.05 | 11.4.05 | 28 | | |
| MTP12: orbits 1585-1684 | 11.4.05 | 9.5.05 | 28 | | |
| planning+commanding | 29.12.04 | 10.4.05 | 102 | | |
| Plan MTP11 | 29.12.04 | 12.1.05 | 14 | | |
| initial PTR freeze | 12.1.05 | | | | |
| PTR, POR lite, DASH gen. | 12.1.05 | 19.1.05 | 7 | | |
| PTR process at ESOC | 19.1.05 | 15.2.05 | 21 | | |
| final PTR freeze | 15.2.05 | | | | |
| PIOR/PMRQ CP64 | 18.2.05 | 4.3.05 | 14 | | |
| short term CP64 | 7.3.05 | 10.3.05 | 3 | | |
| execution CP64 | 13.3.05 | 20.3.05 | 7 | | |
| PIOR/PMRQ CP65 | 25.2.05 | 11.3.05 | 14 | | |
| short term CP65 | 14.3.05 | 17.3.05 | 3 | | |
| execution CP65 | 21.3.05 | 27.3.05 | 6 | | |
| PIOR/PMRQ CP66 | 4.3.05 | 18.3.05 | 14 | | |
| short term CP66 | 21.3.05 | 24.3.05 | 3 | | |
| execution CP66 | 28.3.05 | 3.4.05 | 6 | | |
| PIOR/PMRQ CP67 | 11.3.05 | 25.3.05 | 14 | | |
| short term CP67 | 28.3.05 | 31.3.05 | 3 | | |
| execution CP67 | 4.4.05 | 10.4.05 | 6 | | |
| Total Duration | | | | | |
| initial PTR freeze to first exec. | 12.1.05 | 13.3.05 | 60 | | |
| initial PTR freeze to first exec. | 12.1.05 | 4.4.05 | 82 | | |
| | | | | | |

Science planning: level 1



Science planning: level 2

| Timeline display for plan: plan_1286_1383_FTL_256_FECS_75 | | | | | | | | | | |
|---|------------------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|--|--|--|--|--|
| <u>F</u> ile | | | | | Help | | | | | |
| _ < < [| у итс | | | 5 | n Factor View Number | | | | | |
| | | | 9.02.14.28 | 2005.019.08.57.41 | 2005.019.15.40.55 200 | | | | | |
| | 1289 | 1290 | 1291 | 1292 | 1293 | | | | | |
| | | | | | | | | | | |
| Orbit events Pericentre | 2005.014, 16.09.27 | 2005.018,22.52.48 | 2005.019.05.36.01 | 2005.019.12.19.16 | 2005.019.19.02.28 | | | | | |
| Pericentre NNO | 2005.010.10.05.21 | 2005.014.22.52.46 New Norcia | 2003.017.03.30.01 | 2003.013.12.13.10 | 2005015,1502,20 | | | | | |
| MAD | id | TVC w TVC to C | | 8255 | | | | | | |
| GDS | SZ15 SZ Goldstone | 1 | | 0200 | Goldstone oldstor 3Z14 | | | | | |
| CAN | | • | | - | | | | | | |
| KWGEN_TC | | | | | | | | | | |
| - STAV_OWLT | SX15 | SX74 | | | SX14 SX14 | | | | | |
| тм | мо | TMON | | | TMON | | | | | |
| SSMM Dump Marker | | | | - II | | | | | | |
| SSMM Stop | 12.32.16 | 8.32.17 | 03.12.19 | | 16.39.39 | | | | | |
| SOR_XTX1 | N X-TX-1 OFF TX-1 | X-TX-1 OFF X-TX-1 ON | | K-TX-1 OFF | X-TX-1 ON X-TX-1 OFF X- | | | | | |
| BRC Markers | 17.33.38 | 21.57.08 | | 12.44. | 21 20.4 | | | | | |
| SOR_STX1 | | 3-TX-1 Of | | S-TX-1 OFF | | | | | | |
| Radio Science | | _SC 23.12.49 | | | | | | | | |
| Spacecraft Pointings | | INTENAN EARTH | EARTH | EARTH | EARTH EARTH RT SS_ EARTH | | | | | |
| FDR Markers | | | | | | | | | | |
| Eclipse Heater | IPSE_HEATER_ADDI | IPSE_HEATER_ADDI | IPSE_HEATER_ADDI | IPSE_HEATER_ADD | | | | | | |
| Eclipse | Mars 01:15:25 13.45.59 15.01.24 | Mars 01:15:40 20.29.43 21.45.23 | Mars 01:15:52 03.13.20 04.29.12 | Mars 01:16:03 09.57.06 11.13.09 | Mars 01:16:15 16.40.40 17.56.55 | | | | | |
| Eclipse | | | | | | | | | | |
| Mars Occultations | 14.20.47 <mark>0km</mark> 15.23.01 | 21.05.03 0km 22.06.40 | 03.49.07 <mark>0km</mark> 04.50.10 | 10.33.20 <mark>0km</mark> 11.33.46 | 17.17.23 <mark>0km</mark> 18.17.15 | | | | | |
| Spacecraft Maintena | | faintenand | | | | | | | | |
| Aspera activities | h_off | AS_Switch_off HR_Switch_Off | - | SwitchASASHB_Switch_Off | Switch_off AS | | | | | |
| Hrsc activities Melacom activities | MELACOM Nom OF | | | nn_awiten_on | | | | | | |
| Omega events | Nominal_Switch | OMEGA_Switch_OFF | Nominal_Switch | OMEGA_Switch_OFF | Nominal_Switch | | | | | |
| Omega heater events | | Cincal Control Cont | | oncon_onton_ort | | | | | | |
| PFS activities | PS_Switch_Off | | | | 3 Wake | | | | | |
| PFS pendulum | | | | | | | | | | |
| Spicam activities | Sw Sv SI_Nom | _Switch_OFF SI_Nom_Switch | n_OFF SI_N | Nom_Switch_OFF S | I_Nom_Switch_OFF | | | | | |
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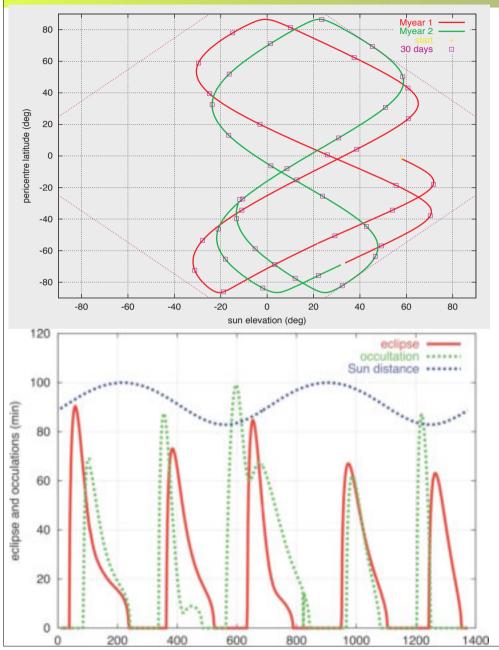
Science planning achievements

- achievements
 - 12 MTP routine phase cycles planned
 - resources used close to maximum
 - no major hickups during Mars operations, including the 5 weeks occultation and the max. eclipse periods
- accuracy:
 - pericenter passage time predict for MTP planning: ±10 sec (spec was 2 min)
 - pointing: better than 0.01 deg = 36 arcsec = 0.175 mrad (spec was 0.05 deg)
- extra operations
 - MER-MEX communications demo passes
 - Cassini/Huygens VLBI
 - Spot pointing tests

Science planning outlook

- problem areas
 - on board data overflow during low data rate phases
 - long lead times
 - data gaps
- outlook- nominal mission
 - Marsis deployment
 - 4 new pointing modes (spot pointing with +Z and HGA, specular, rotation)
 - very high data rate phase: 70% of the nominal mission data still to come
 - eclipse phase #3

Extended mission



- resources: fuel (per bookkeeping)
 - 39.9 kg per 12/11/04
 - 2.3 kg/year
- resources: power
 - aphelion @ mission day 900
 - 22.5% battery degradation