

Status GRACE Mission Operations



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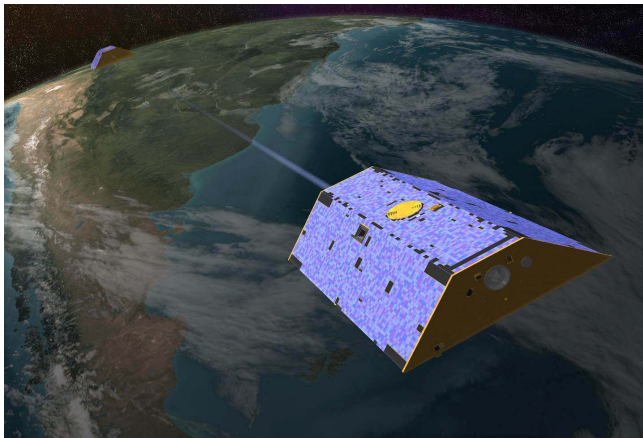
Status GRACE Mission Operations

Orbit Status 10 – Oct 2013

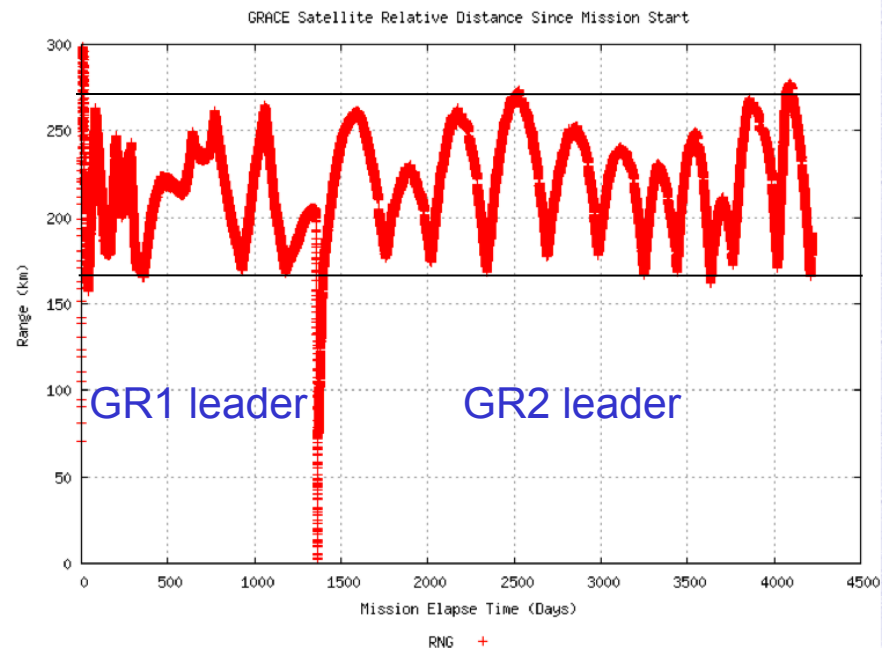


Celebrated 11 Years in Orbit - 17 March 2013!!

- Semi-major axis: 6808 km, 430 km above 6378 km
- Altitude decrease: ~ 28 m/day
- Inter-satellite Distance: 220 km (\pm 50 km)
- Last Orbit Maneuver: 23 September 2013



- 4225 days in orbit
- 64751 revolutions completed

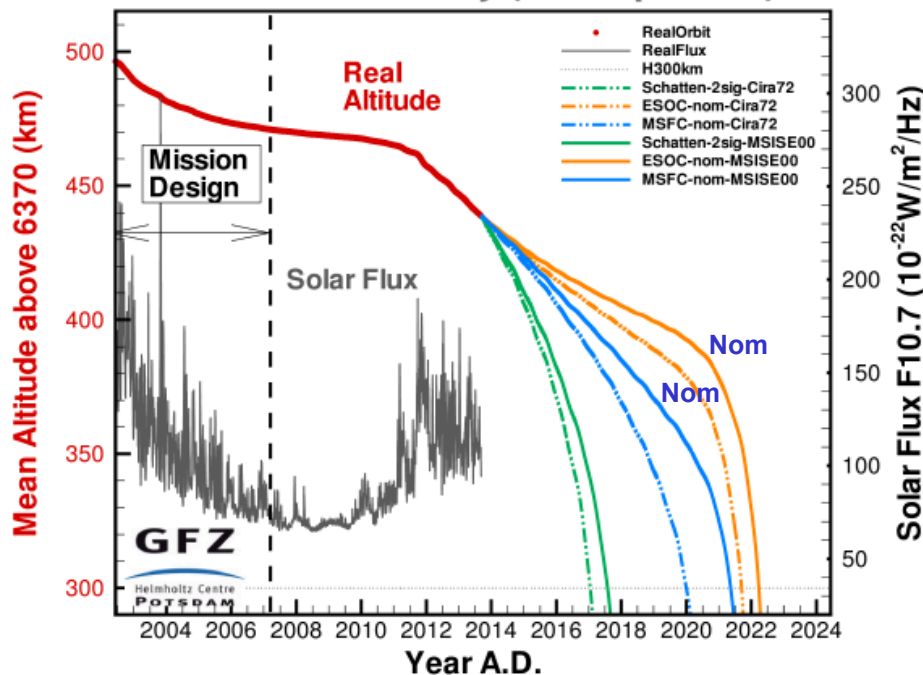


Status GRACE Mission Operations

Mission Lifetime Predictions



GRACE-1 Decay (11-Sep-2013)



Cold gas resources:

- GR-1: 10.9* kg (i.e. ~ 5.0 years)
- GR-2: 12.9* kg (i.e. ~ 5.0 years)

End of Life (pred.): GR-1 2018/2019
(gas/decay*) GR-2 2018/2019

* Based on MSFC-Nom

Thruster actuations up to now (assured 1 Mio. per thruster):

- Roll: GR-1: 0.90 Mio GR-2: 0.89 Mio
- Pitch: GR-1: 0.31 Mio GR-2: 0.29 Mio
- Yaw: GR-1: 1.16 Mio * GR-2: 1.08 Mio *

* Yaw thruster is used the most!

Satellite Status

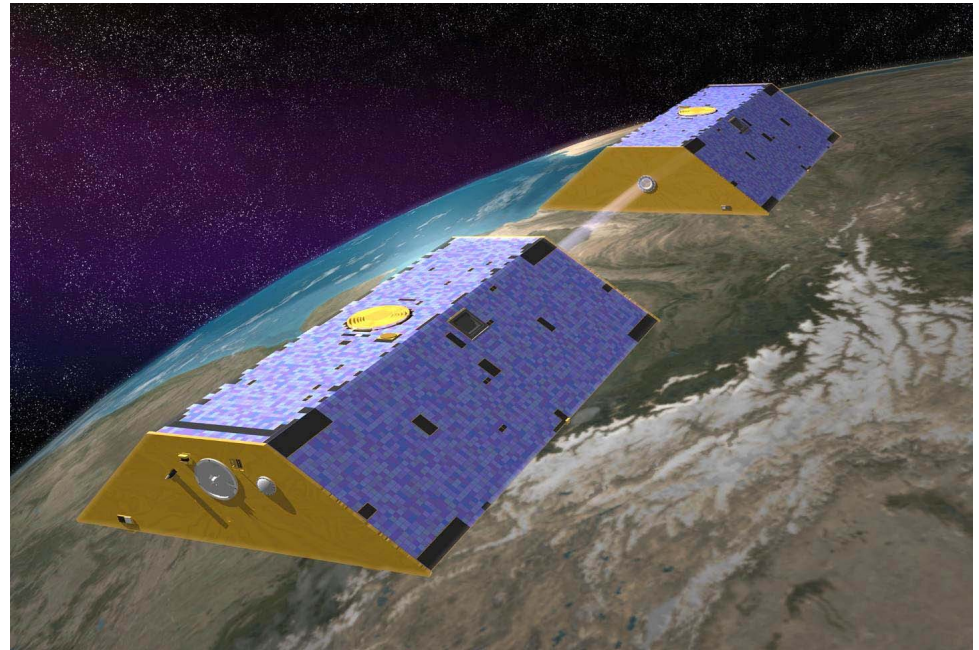


Overall health excellent, with exception of batteries:

- GR-1: cell failure Aug 2009
 - 2nd cell failed in April 2011
- GR-2: cell failure Aug 2007
- No failures since April 2011

Fault tolerance status:

- GR-1
 - IPU-Red Anomaly on 9 Mar 2012
 - Relies on 4 backup units: Microwave, Ultra-stable Oscillator, Instrument Control Unit of the Accelerometer, Instrument Processing Unit (IPU)
- GR-2
 - TX-1 Failure on 15 Nov 2011
 - Relies on 2 backup units: IPU and TX-2



Battery Life Extension Measures:

- Daily Battery Charge Management
 - Battery Temps Below 15°C
- Yaw Turns during Full-Sun
- ICU, MWA off at low beta prime

Battery Status



Battery design and initial parameters GR1 & GR2 in deep eclipse

- 18-Ahrs capacity; 5-yr life; 20 Ni-H₂ cells — tolerant to one (1) failed cell
- In 2002, temperature: 18°C & 14°C; depth of discharge: 4.2 & 4.7 Ahrs (26%)

Current situation

- GR-1 is operating with 18 cells (2 failed) and GR-2 with 19 cells (1 failed)
- Useable capacity is currently limited to ~2.5 Ahr and is slowly decreasing
 - Power for temperature control has been minimized. Even so,
 - 3.2 Ahrs is needed to keep all science instruments ON during deep eclipse.
 - The intervals with science instruments turned OFF is increasing
 - 42, 44, and 50-days in the last three deep-eclipse periods.

Measures to extend Battery life

- Average operating temperatures are minimized, and those above 15°C avoided.
- Battery charging is adjusted daily by time-tagged command to minimize stress
 - A recent refinement reduces peak charge currents from >15 amps to <10 amps
 - The resulting lower temperatures (up to 2°C) should improve remaining life
- Discharge/charge cycles are induced during periods of full-sun (next occurs in Nov. 2013)
 - Creates small science data gaps (<1 hour) separated by several days



Star Camera Status

New code and star catalogs were uploaded in 2011 to both satellites

- Gains and thresholds have been re-optimized to reflect the current and unique performance of each of the 4 cameras.
- GR-2 SCA-1 is the worst performing camera.
 - Sensitivity to stray light hampers operation when the Sun is close to the FOV. The size of the stray-light FOV has increased ($\sim \pm 50^\circ$).
 - Fuel consumption increases when this camera is PRIME.

Mitigation actions:

- In the fall of 2012 we optimized SCA parameters on GR-2 SCA-1 using AOCS fuel consumption as a metric.
- We minimize the use of this camera when possible to do so.
- No further improvements are expected.

Satellite Events since Last GSTM * - 1



Hardware Swaps: None

Software Uploads: None

Parameter Updates:

IPU Default library Updates

- Version 9: October 2012
- Version 10: October 2012
- Version 11: March 2013
 - Included Updated KBR Tone Predicts

Star Camera Parameter Revisions

- DACSpan and Threshold revisions were implemented on both satellites during the year in order to improve performance
- Parameter revisions are documented in the IPU Configuration File



Satellite Events since Last GSTM - 2

Maintenance Maneuvers (GR-2)

- 19-Mar & 7-May & 23-Sep 2013

Regularly Commanded OBDH Reboots

- GR-2: 13-Sep 2012 (Warm Boot)
- GR-2: 12-Jun 2013 (Cold Boot)
- GR-1: 25-Jul 2013 (Cold Boot)

Spontaneous OBDH Reboots

- GR-1: 29-Oct 2012 – Connected with MWA Switch On

Center-of-Mass Calibrations

- 4-Jan, 4-Jun & 15-Jun 2013 (No CM Trim Necessary)

Drops to Coarse Pointing Mode

- GR-1: 6 – 9 Dec 2012 (55 hr data loss due to SCA-2 Invalid Output)
 - Included a 180° Yaw Turn (to bring SCA-1 online)
- GR-1: 16-Dec 2012 (repeat of SCA-2 anomaly)
- GR-1: 24-Mar 2013 (invalid SCA-1 data)



Satellite Events since Last GSTM - 3

Load Reduction actions (around $\beta'=0$ crossing)

2012

25 Sep: GR-1 ICU Off ($\beta'=19^\circ$)
 GR-2 ICU Off ($\beta'=19^\circ$)
 2 Oct: GR-1 MWA Off ($\beta'=13^\circ$)
 GR-2 MWA Off ($\beta'=13^\circ$)
14 Oct 2012 $\beta'=0^\circ$
 29 Oct: GR-1 MWA On ($\beta'=-16^\circ$)
 30 Oct: GR-2 MWA On ($\beta'=-17^\circ$)
 5 Nov: GR-1 ICU On ($\beta'=-23^\circ$)
 6 Nov: GR-2 ICU On ($\beta'=-24^\circ$)

42 Days

2013

26 Feb: GR-2 ICU Off ($\beta'=-22^\circ$)
 27 Feb: GR-1 ICU Off ($\beta'=-21^\circ$)
 28 Feb: GR-2 MWA Off ($\beta'=-20^\circ$)
 1 Mar: GR-1 MWA Off ($\beta'=-19^\circ$)
19 Mar 2013 $\beta'=0^\circ$
 4 Apr: GR-2 ICU On ($\beta'=17^\circ$)
 5 Apr: GR-1 ICU On ($\beta'=18^\circ$)
 10 Apr: GR-2 MWA On ($\beta'=23^\circ$)
 11 Apr: GR-1 MWA On ($\beta'=24^\circ$)

44 Days

5 Aug: GR-1 MWA Off ($\beta'=24^\circ$)
 6 Aug: GR-2 MWA Off ($\beta'=23^\circ$)
 7 Aug: GR-1 ICU Off ($\beta'=22^\circ$)
 8 Aug: GR-2 ICU Off ($\beta'=20^\circ$)
28 Aug 2013 $\beta'=0^\circ$
 13 Sep: GR-1 ICU On ($\beta'=-16^\circ$)
 16 Sep: GR-2 ICU On ($\beta'=-20^\circ$)
 24 Sep: GR-1 MWA On ($\beta'=-28^\circ$)
 24 Sep: GR-2 MWA On ($\beta'=-28^\circ$)

50 Days

Since last GSTM, 64.4%* of time all instruments are operating

* Includes Three $\beta'=0$ Crossings



Satellite Events since Last GSTM - 4

Annual Operations Status Review at GSOC

- Assessed health, existing risk items and life expectancy of the satellites

90° -Yaw Attitude Testing

- Confirmed flying at constant 90° -yaw attitude is reliable & reduced the load on the battery by over 30%
- Science is not possible in this attitude, but it allows the satellites to survive periods with eclipsing orbits without completely depleting fuel resources
- The operational procedures are ready to use if it becomes necessary

Revisions to Fault Protection

- Further Survival & Heater Table H refinements for power margin
- Lowered Macro 82 (ICU & MWA Off) and DNEL trigger thresholds
- Increased KBR Missed Interrupt Detection Floor

Hot Pixel Surveys

- Survey #21: 8 & 20 Oct 2012
- Survey #22: 13 & 25 Mar 2013
- Survey #23: 22 Aug & 3 Sep 2013

Solar Eclipse (by the Moon): 13 Nov 2012 & 9 May 2013

- Batteries performed nominally and no load shedding was required



Satellite Events since Last GSTM - 5

Miscellaneous Unexpected Events

- 26 Dec 2012: Forced IPU Reboot (GR-1) to restore Occultation Data
 - This was due to a rare, but known, IPU issue
- 10 Apr 2013: Macro 40 (switch to BCR-Red) Trigger (GR-2)
 - Occurred just after MWA Turn On
 - Revised battery charging scheme induced a thermal run-away
 - Macro adjusted accordingly until power stabilized
- 7 May 2013: Macro 82 (ICU & MWA Off) Trigger (GR-2)
 - Triggered due to low voltage (just below set point)
 - During the turn to AHM & just prior to the Maintenance Maneuver
 - Macro 82 set point was reduced & Macro 40 trigger was increased
 - ICU & MWA were powered back on
 - Macro 82 and DNEL triggers permanently lowered
- 23 Jul 2013: Macro 40 Trigger (GR-2)
 - Tripped several times due to an incorrect Macro 41 (switch to BCR-Main)
 - Macro 41 was corrected and this has not reoccurred



Planned Satellite Events: 2013 - 2014

Event	Date
Alternate Battery Charging Scheme	Oct 2013
Lunar Eclipse	Nov 2013
Yaw Turns for Battery Discharge (full-Sun)	Nov 2013
CoM Calibrations	Nov 2013
Prime SCA Head Switch	Close to 2-Feb 2014 ($\beta'=0^\circ$)
ICU / MWA Switch Off	20-25 days before/after $\beta'=0^\circ$
GR-2 Planned OBDH Reboot	Mar 2014
Maintenance Maneuver	Apr 2014
Yaw Turns for Battery Discharge (full-Sun)	Apr 2014
CoM Calibration	Apr 2014
GR-1 Planned OBDH Reboot	Apr 2014
Prime SCA Head Switch	Close to 14-Jul 2014 ($\beta'=0^\circ$)
ICU / MWA Switch Off	20-25 days before/after $\beta'=0^\circ$

Status GRACE Mission Operations

German Space Operations



GSOC

Neustrelitz GS &
Raw Data Center



Control Center
Oberpfaffenhofen



Weilheim GS



GFZ Ny-Ålesund GS

Status GRACE Mission Operations

GSOC Activity since Last GSTM



- “Recommendations”: 1119 (directives to the operators)
 - 190 more than 2012
 - Daily Battery Management -> the driver
- Configuration: 2 Updates to the IPU Default Libraries
- Anomaly Reports: 47 opened
26 currently open ARs
Team continues to aggressively close ARs
 - 10 Satellite-related *
 - 11 Ground-related
 - 5 Ops-related

* Satellite-related anomalies are distributed as follows:

- ✓ 3 Instrument Processing Unit (IPU)
- ✓ 3 Thermal / Power related
- ✓ 2 On-Board Data Handler (OBDH)
- ✓ 2 Star camera (SCA)





Summary

GRACE celebrated 11 years in orbit on 17 March 2013!!

- Both satellites continue to operate nominally
- No additional loss of redundancy has occurred in the past year

Pro-active battery management continues to be labor intensive, but effective in maintaining battery health

- No failures since the 2nd cell failure on GR-1 in April 2011
- New battery charging scheme has been implemented to maximize charge efficiency (two charge cycles per sunlight phase)
- Instruments powered off around $\beta' = 0^\circ$

Excellent performance from the ground segment continues

- GFZ Ny-Ålesund ground station contacts provide improved visibility into the battery performance for both satellites

2013 NASA Group Achievement Award for GRACE Battery Management!

GRACE Mission Operations were approved and funded through 2015 following the 2013 NASA Senior Review

