The successful US/German satellite gravity mission GRACE comes to an end after 15 years

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On March 17, 2002, the twin satellites of the NASA/German Gravity Recovery and Climate Experiment (GRACE) were launched in order to make precise measurements of the Earth´s gravity field. GRACE has lasted three times as long as originally planned for more than 15 years. Now it has ended science operations.

Following the age-related failure of a battery cell on one of GRACE's two satellites, GRACE-2, contact was lost already in September. There are 20 battery cells on each satellite, and GRACE-2 had previously lost seven other cells and was critically low on fuel. Mission managers were able to restore communications with the spacecraft, and analyses revealed the battery had recovered its full voltage. The mission team made plans for one final science collection beginning in mid-October, when the satellites would be in full view of the Sun. Since then, GRACE-2 has periodically hibernated when there was insufficient Sun to power the instruments.

On Oct. 12, as the team prepared to resume science data collection, it became apparent that even with the help of full-Sun conditions, the remaining battery capacity on GRACE-2 would not be sufficient to reliably operate its science instruments and telemetry transmitter. The mission's Joint Steering Group comprised of all U.S./German mission partners (NASA's Jet Propulsion Laboratory, Pasadena, California, Deutsches Zentrum für Luft- und Raumfahrt (DLR, the German

Aerospace Center) and the Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences) made a decision and announced GRACE-2 will be decommissioned. Since both satellites are required to make the science measurements, the loss of GRACE-2 means GRACE will no longer be able to continue its dual satellite science mission.

"We look back with pride and gratitude on the GRACE mission" says Prof. Dr. Reinhard Hüttl, Scientific Executive Director and Chairman of the Board at the GFZ. "During the 15 years of the mission operation, the satellite tandem has measured the gravity field of the Earth and its variations in a highly precise manner, which helps us, for example, to accurately document changes in groundwater storage or in glacial retreat. Furthermore, the resulting influence on sea level rise can be detected thanks to the GRACE measurements. The mission has, thus, substantially contributed to a better understanding of the system Earth."

Since 2010, GRACE's multi-national mission operations and science data analysis teams have overcome numerous technical challenges and developed innovative methods to work around the limitations imposed by aging batteries and limited fuel for flight control to allow the mission to continue to provide its valuable data more than 10 years beyond its intended lifetime.

GRACE-2 is currently orbiting at 305.3 kilometers above Earth, 655 kilometers ahead of and 1,3 kilometers below GRACE-1. With GRACE-2 out of fuel, atmospheric drag on the satellite will increase the separation distance and lower GRACE-2's altitude relative to GRACE-1. There is no risk of a collision with GRACE-1, and GRACE-2's orbital altitude does not pose a hazard to other operational satellites.

GRACE-2 will be safely deorbited and is expected to reenter the atmosphere and burn up by mid-to-late November. A few small pieces are expected to survive reentry and reach the ground, but the risk they

pose to anyone is minimal and well within NASA requirements for satellite reentry and orbital debris.

Operations of GRACE-1 will continue, with all of its remaining fuel being used to complete a series of accelerometer calibration maneuvers that will be used to improve the scientific return and insights from the 15 year record left by GRACE. All mission activities involving GRACE-1 will be completed by the end of the year, followed by decommissioning of GRACE-1 and atmospheric reentry in early 2018. NASA and the German Space Operations Center will jointly monitor both GRACE satellites as they deorbit and reenter the atmosphere.

"The GRACE Mission Operations Team composed of DLR/GSOC, Airbus Defense and Space GmbH, JPL, University of Texas and GFZ has done a superb job to extend the nominal mission life time by more than a factor of three", says Prof. Frank Flechtner, co-principal investigator at GFZ. "It is of course a great pity that the monthly observation of mass transport in system Earth has ended after 15 and a half years. However, we now look forward to a successful launch of the successor tandem mission GRACE Follow-on in early 2018. It promises even more precise measurements of the Earth's gravity field due to an innovative Laser Ranging Interferometer, a technology demonstrator for next generation gravity missions developed by a German/American joint collaboration, and will thus yield further important contributions to Earth system science."

The principle of the mission: Each of the twin GRACE satellites operates by transmitting microwave signals that are received by the other GRACE satellite. The timing of the received signals is used to precisely measure the small accelerations and decelerations caused by changing mass on the Earth below the spacecraft, which alter the distance between them very slightly. GRACE's monthly maps of regional variations in global gravity over the past 15-plus years have shown how water, ice and

solid Earth material on or near Earth's surface has moved. To learn more about some of GRACE's science accomplishments, visit:

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