Next-generation GRACE satellites arrive at launch site

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A crate containing one of the twin Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) satellites is offloaded from an air freighter at California's Vandenberg Air Force Base Dec. 12 following a transcontinental flight from Germany. GRACE-FO is scheduled for launch next spring. Credit: USAF

A pair of advanced U.S./German Earth research satellites with some very big shoes to fill is now at California's Vandenberg Air Force Base to begin final preparations for launch next spring.

Following a year-long test campaign by satellite manufacturer Airbus Defence and Space at IABG in Ottobrunn, near Munich, Germany, the twin Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) satellites were loaded aboard an air freighter at Munich airport Dec. 11 and arrived at the launch site on California's central coast Tuesday, Dec. 12. GRACE-FO will provide continuity to the Earth climate data record of the extremely successful predecessor GRACE, which completed its science mission in October after more than 15 years in orbit.

GRACE-FO will extend GRACE's legacy of scientific achievements, which range from tracking mass changes of Earth's polar ice sheets and estimating global groundwater changes, to measuring the mass changes of large earthquakes and inferring changes in deep ocean currents, a driving force in climate. To date, GRACE observations have been used in more than 4,300 research publications. Its measurements provide a unique view of the Earth system and have far-reaching benefits to society, such as providing insights into where global groundwater resources may be shrinking or growing and where dry soils are contributing to drought. GRACE-FO is planned to fly at least five years.

The GRACE-FO spacecraft will undergo final tests before being integrated atop a SpaceX Falcon 9 rocket, where they will share a ride to space with five Iridium NEXT communications satellites.

An air freighter containing the twin Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) satellites lands at California's Vandenberg Air Force Base Dec. 12. Credit: USAF

"With this milestone, we are now in position to launch GRACE Follow-On and restart the valuable observations and science that ceased in mid-2017 with the end of the GRACE science mission," said Michael Watkins, director of NASA's Jet Propulsion Laboratory in Pasadena, California, and GRACE Follow-On science team lead.

After a few months of in-orbit checkout, GRACE-FO will track changes in the distribution of liquid water, ice and land masses by measuring changes in Earth's gravity field every 30 days. GRACE-FO will essentially measure how much mass is gained or lost each month on the

continents, in the oceans, and in the ice sheets. These data will improve scientific understanding of Earth system processes and the accuracy of environmental monitoring and forecasts.

The continuous movement of masses of water, ice, air and the solid Earth that GRACE-FO will track is driven by Earth system processes such as:

- Terrestrial water cycle processes, such as precipitation, droughts, floods, changes in ice sheets and land glaciers, evaporation from the oceans, and groundwater use and storage.
- Tectonic processes, such as earthquakes and variations in Earth's lithosphere (the rigid outer layer of our planet that includes the crust and upper mantle) and mantle density.

Two crates containing the twin GRACE-FO satellites are offloaded from an air freighter at California's Vandenberg Air Force Base Dec. 12. GRACE-FO will provide continuity to the Earth climate data record of the extremely successful predecessor GRACE mission, which operated for more than 15 years. Credit: USAF

The GRACE-FO satellites will be launched into a polar orbit at an altitude of about 311 miles (500 kilometers). Flying 137 miles (220 kilometers) apart, the satellites will use a JPL-built microwave ranging system to take continuous, very precise measurements of the variations in the distance between each other. These variations are caused by minute changes in the gravitational pull on the satellites from local changes in Earth's mass below them. The microwave ranging data are combined with GPS tracking for timing, star trackers for attitude information, and an accelerometer built at ONERA in France to account for non-gravitational effects, such as atmospheric drag and solar radiation. From these data, scientists will calculate how mass is redistributed each month and monitor its changes over time.

Each satellite will also carry an instrument called an atmospheric limb sounder that will provide an innovative and cost-effective technique to measure how much signals from GPS satellites are distorted by the atmosphere. The sounders will provide up to 200 profiles of atmospheric temperature and water vapor content each day to aid weather forecasting.

While similar to their predecessor GRACE satellites, GRACE-FO incorporates design upgrades gleaned from 15 years of GRACE operations that will improve satellite performance, reliability and mission operations. GRACE-FO will also fly a new, more precise inter-

satellite laser ranging instrument, developed by a German/American joint venture, which will be tested for use in future generations of GRACE-like missions.

Provided by Jet Propulsion Laboratory