November 2014

AEROSPACE AMERICA

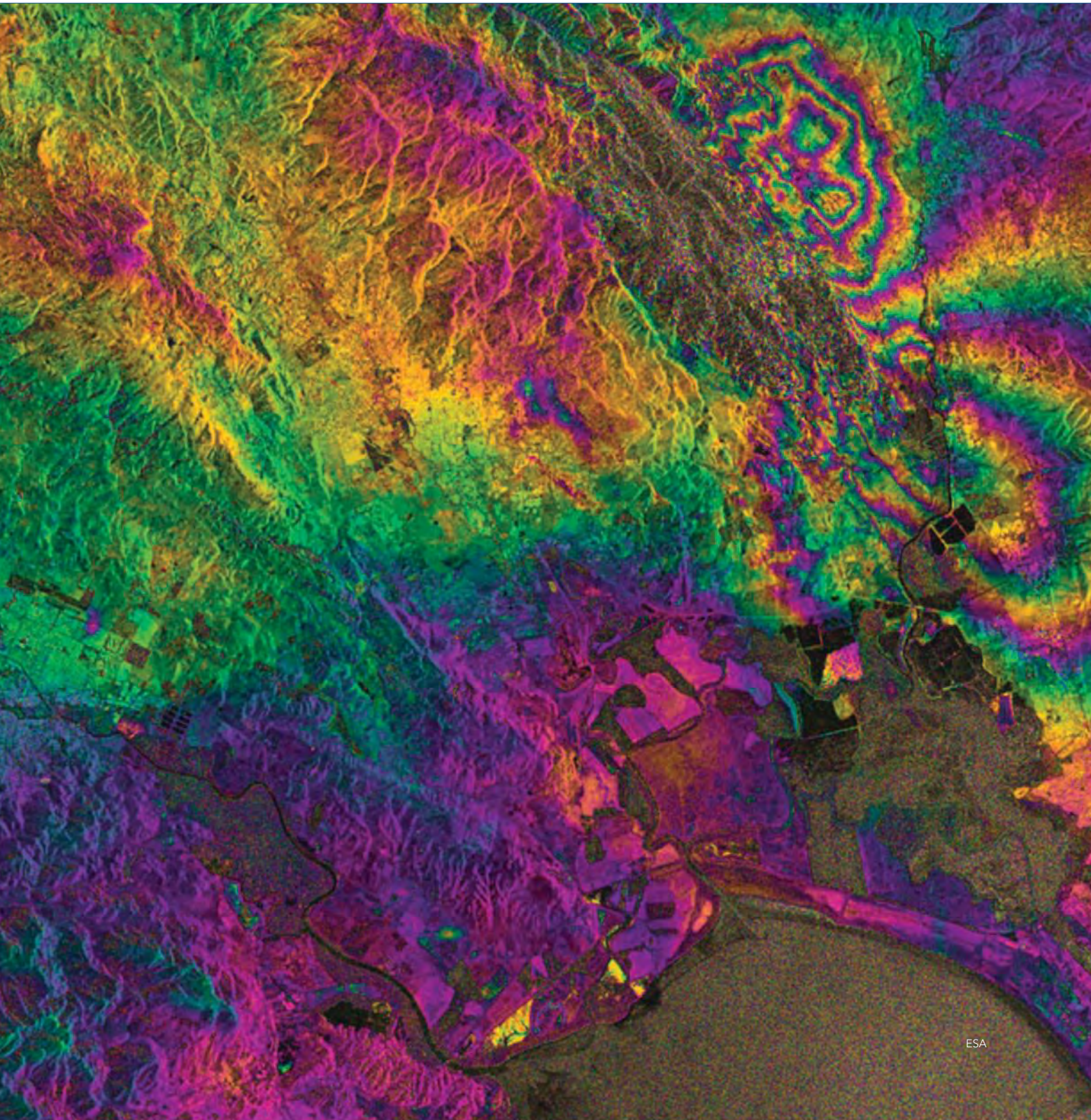
ORION

The 4-hour flight and fiery re-entry that could give NASA its mojo back
page 24

Proactive on cybersecurity/page 30
Earth-observing Sentinels/page 34
Aireon's Thoma on airliner surveillance
page 22

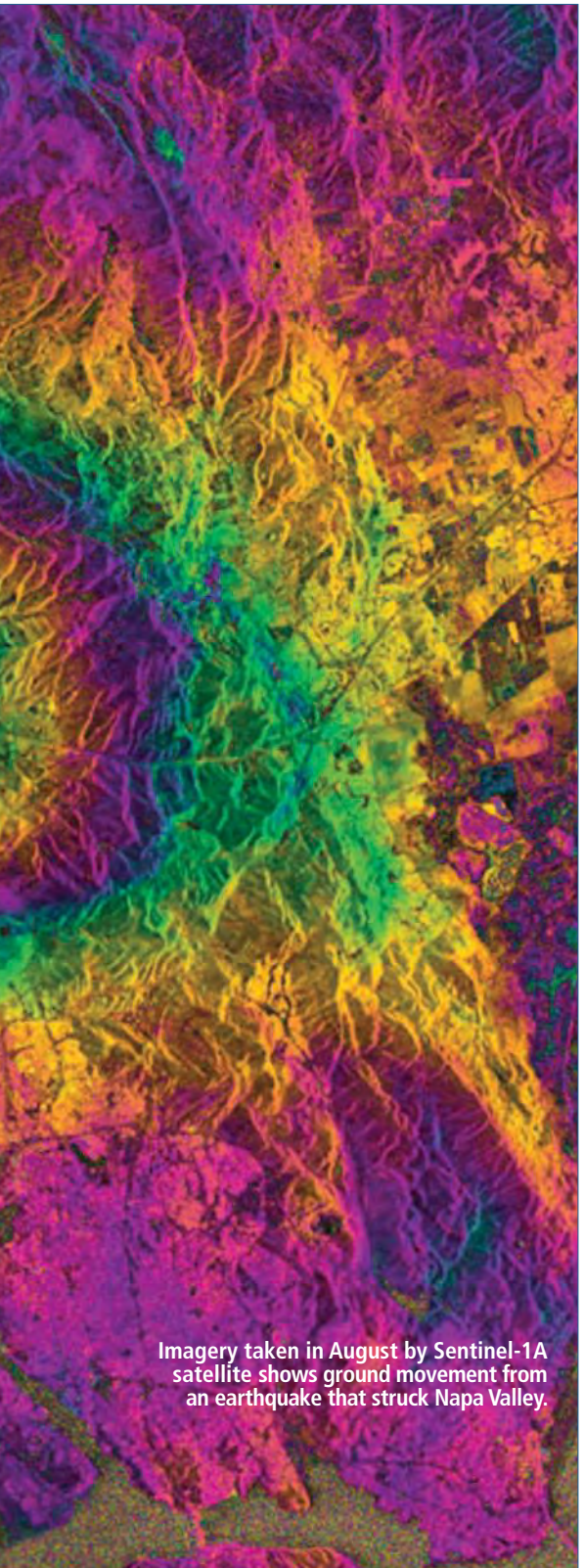
A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Europe's Mission to



ESA

Earth



Imagery taken in August by Sentinel-1A satellite shows ground movement from an earthquake that struck Napa Valley.

Europe plans to field a fleet of 15 satellites and five hosted payloads that would monitor Earth's environment continually for many years to come. Some instruments would measure air pollution that is contributing to climate change. Others would watch for rising sea levels or shifts in the land that could portend earthquake risk. NASA once had a similarly ambitious Earth-observing plan but was unable to complete it. Marc Selinger says Europe is confident that it can get its Sentinel constellation to orbit.

British scientist Tim Wright was thousands of miles away from California when a major earthquake rattled the state's Napa Valley wine country in August. Pictures from Europe's Sentinel-1A, a 2,300-kilogram radar satellite launched in April, helped him quickly assess the rupture.

By comparing images taken days before and after the quake, Wright and his colleagues confirmed that the West Napa Fault, previously thought to be benign, had triggered the upheaval. Their analysis also revealed that the fault extends farther north than once thought.

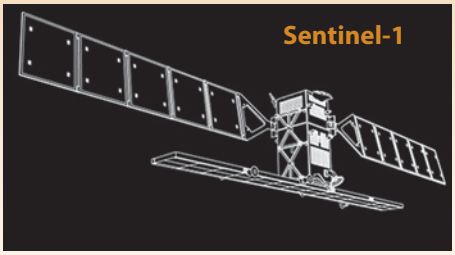
Before Sentinel-1A, such discoveries would have been all but impossible.

"The big difference about Sentinel-1 is that it will be acquiring data systematically for all of the seismic belts, and so we should be able to see almost every earth-

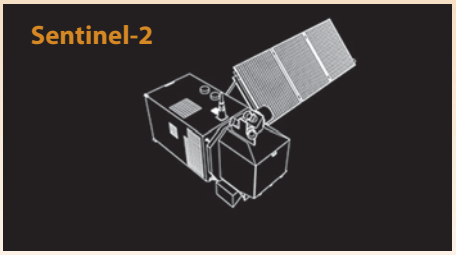
By Marc Selinger

ALL EYES ON EARTH

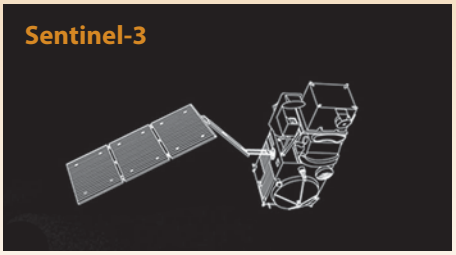
Europe's Sentinel satellites will gather everything from pollution readings to sea surface heights.



Sentinel 1A, 1B, 1C, 1D
Polar-orbiting satellites equipped with imaging radars.
Purpose: Track sea ice, oil spills, marine wind, ocean waves, land-use changes and land deformation. Aid emergency response to earthquakes and floods.
Launch Dates: **1A:** April 2014
1B: 2016
1C: 2021
1D: 2023



Sentinel 2A, 2B, 2C, 2D
Polar-orbiting satellites equipped with multispectral sensors.
Purpose: Monitor vegetation, soil and water cover, inland waterways and coastal areas.
Launch Dates: **4A:** 2015
4B: 2016
4C: 2022
4D: 2023



Sentinel 3A, 3B, 3C, 3D
Multi-instrument satellites.
Purpose: Measure sea-surface and land-ice topography, sea- and land-surface temperature, and ocean and land color.
Launch Dates: **3A:** 2015
3B: 2017
3C: 2023
3D: 2024

quake that causes damage in the continents," says Wright, a professor at the University of Leeds and the director of the Centre for the Observation and Modeling of Earthquakes, Volcanoes and Tectonics, or COMET. "Other satellites can make the same kinds of measurements, but they do not have the capacity to be switched on all the time. Or they are semi-commercial systems that require tasking, which would be fine if we knew where and when the earthquakes were going to happen."

ULA

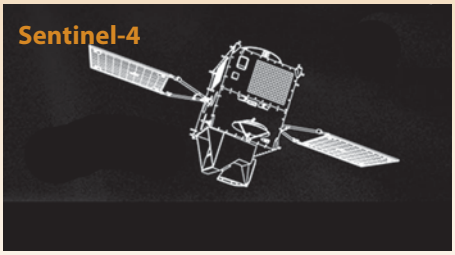
United Launch Alliance's Atlas 5 is one of the three candidates under consideration to be the launch vehicle for the Sentinel-6 satellites.

COMET plans to use Sentinel-1A data to monitor slow shifts in the ground that can precede quakes. Such information will help public officials ensure that building codes in earthquake-prone regions are up to date.

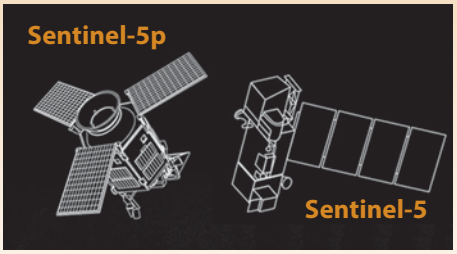
Such is the promise of Europe's Sentinel project: Erect a vast constellation of satellites that is always on, constantly collecting almost every kind of data imaginable about the Earth. European officials consider the Sentinels one of two flagship space programs managed by the European Commission, with the other being the Galileo global navigation satellite system. Both programs seek to assert European technology independence in space.

The challenge for Europe, says a veteran American space expert, will be to marshal the staying power to get all the Sentinels to orbit.

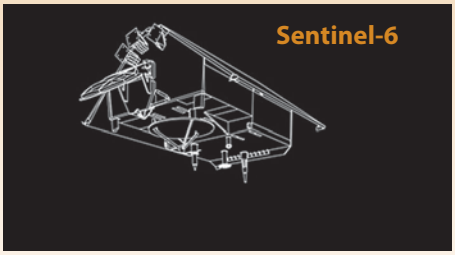
"I wish them well, as I know firsthand how difficult it is to sustain such efforts here in the U.S. across administration, congressional and NASA leadership changes," says Bill Townsend, who was acting associ-



Sentinel 4A, 4B
Spectrometer payloads for EUMETSAT geostationary weather satellites.
Purpose: Air quality monitoring and forecasting.
Launch Dates: **4A:** 2021
4B: TBD



Sentinel 5p, 5A, 5B, 5C
5p (precursor) is a low-Earth-orbit satellite. 5A, 5B and 5C are payloads on EUMETSAT polar-orbiting satellites.
Purpose: Atmospheric monitoring.
Launch Dates: **5p:** 2016
5A: 2021
5B: TBD
5C: TBD



Sentinel 6A, 6B
Satellites with radar altimeters to measure global sea-surface height.
Purpose: Operational oceanography and climate studies.
Launch Dates: **6A:** 2020
6B: 2025

ate administrator for earth science when NASA made a similar attempt in the 1990s.

New Copernican Revolution

Sentinel is part of the European Union's Copernicus program, which until December 2012 was known as GMES, for the Global Monitoring for Environment and Security system. The name Copernicus reflects the goal of revolutionizing the world's perceptions of Earth just as astronomer Nicolaus Copernicus improved the world's understanding of the cosmos by showing that Earth orbits the sun, not the other way around.

The European Commission, the EU's executive arm, oversees Copernicus. The European Space Agency manages the space segment and the European Environment Agency furnishes data from terrestrial sources, including ground-based weather stations and ocean buoys.

The space component includes 20 new spacecraft: 15 ESA satellites, plus five ESA payloads that will be hosted on satellites operated by the European Organisation for the Exploitation of Meteorological Satellites, or EUMETSAT. These spacecraft are to comprise six lines of Sentinel satellites, or "families" in Sentinel parlance, each with distinct missions ranging from tracking oil spills to monitoring air quality.

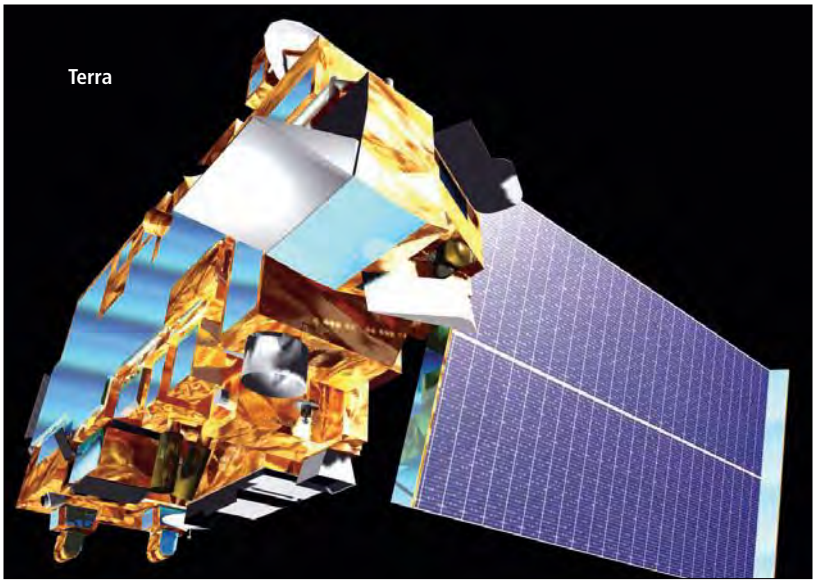
Some satellites will replace aging spacecraft, while others will perform missions that were previously unaddressed. Data from all of the satellites will be available free of charge and mostly online to policymakers, researchers and businesses.

The first satellite, Sentinel-1A, was launched by Arianespace in April on a Soyuz rocket from Europe's Spaceport in French Guiana. Thales Alenia Space designed and built the satellite and Airbus Defence and Space provided the radar, which can pierce clouds and darkness. Sentinel-1A ground images are at least four times finer in resolution than those of its predecessor satellite, Envisat.

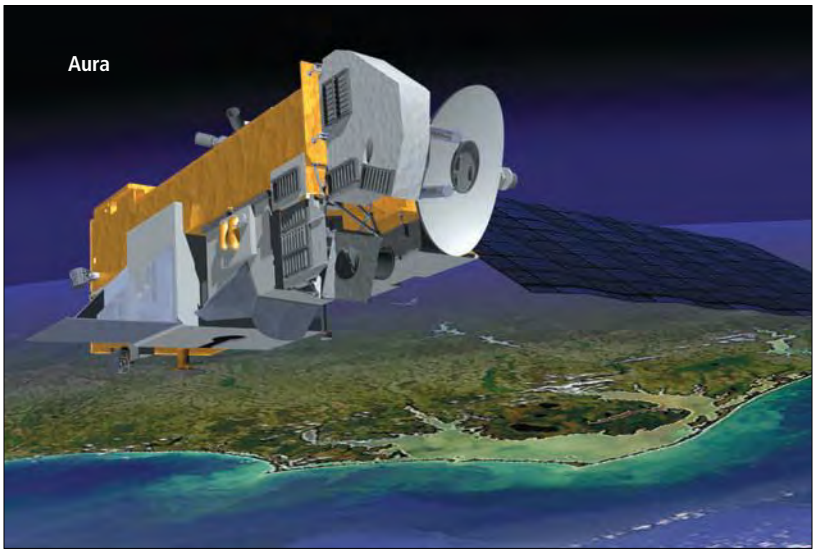
Besides earthquake mapping, Sentinel-1A is helping track landslides in Norway, river flooding in Namibia and ice cap motion in the Arctic Ocean. It will be joined by its identical twin, Sentinel-1B, in 2016. Having the pair in orbit at the same time will make it possible to revisit a particular spot on Earth every six days instead of 12.

Each family has a built-in retirement plan. When the initial satellite or satellites reach the end of their service lives, new ones will be launched. For instance, 1A and 1B, which are expected to last seven years each, are scheduled to be succeeded by 1C in 2021 and 1D in 2023.

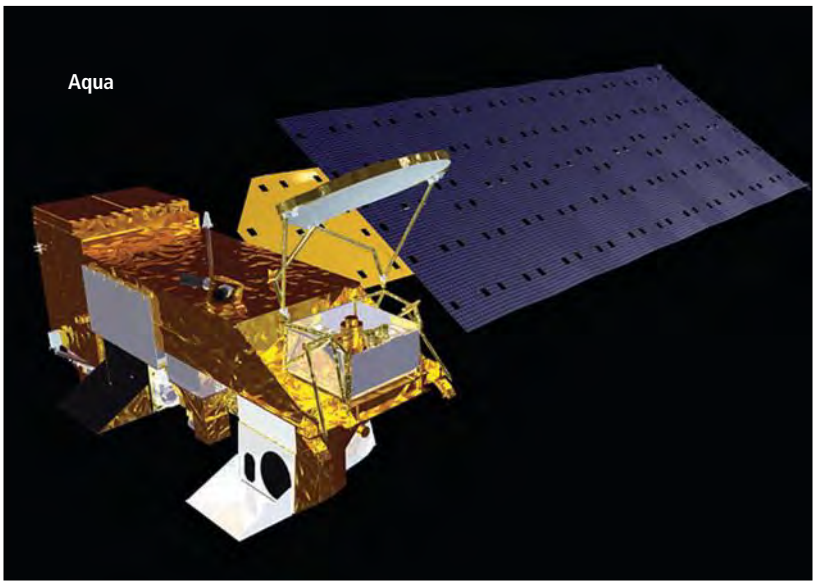
ESA contends that Sentinel will be more comprehensive than the U.S. Earth-observation arsenal, which was assembled



NASA



NASA



NASA

Due to budget constraints, NASA's Earth Observing System of the 1990s was scaled back to a single set of three main satellites — Terra, Aura and Aqua — which remain in service but are well beyond their design lives.

in piecemeal fashion. The United States has no civilian radar counterpart to Sentinel-1. As for Sentinel-2, the U.S. Landsat satellites are similar in that they collect imagery for agriculture and other uses, but the sensors aboard Sentinel-2 will cover wider areas than Landsat sensors.

"In the U.S., there is no Earth-observation program comparable to Copernicus, both in terms of objectives and size," says Guido Levrini, ESA program manager for the Copernicus space segment.

The United States does have a limited role in Sentinel, though. The U.S. government will participate in Sentinel-6, which will continue the Jason series of ocean-monitoring satellites that the United States and Europe have jointly fielded for over two decades.

The United States will provide three payload instruments and a still-to-be-determined launch vehicle for each of two Sentinel-6 satellites. Launch vehicle candidates are SpaceX's Falcon-9, Orbital Sciences Corp.'s Antares and United Launch Alliance's Atlas 5.

NOAA leads the U.S. contribution on Sentinel-6, with support from NASA's Jet Propulsion Laboratory and the Navy. Development of the first Sentinel-6 is to begin in 2015.

Townsend says that continuing this partnership is critical to improving the United States' understanding of climate change. The Sentinel-6 satellites will measure how the oceans redistribute energy that is pumped into them from sunlight and by greenhouse gases that trap heat in the atmosphere.

The United States has a smaller role in two other Sentinel families. These efforts include sharing data between Landsat 8 and Sentinel-2 satellites and between the U.S. Suomi weather satellite and the Sentinel-5P satellite.

Finding funding

Despite government budget constraints across Europe, Levrini says Copernicus has enough EU funding in place — the equivalent of $4.1 billion U.S. — to sustain it through 2021. A majority of the Sentinels will have been launched by then. In addition, the allocated money covers the development of satellites launched after 2021.

"The successful deployment of Coper-

nicus in the coming years and the achievement of the program objectives" will help reaffirm support among policymakers for continuing to finance satellite operations beyond 2021, says Levrini.

As envisioned in the 1990s, NASA's Earth Observing System was supposed to be a recurring series of satellites but ended up being scaled back to a single set of three main satellites — Terra, Aqua and Aura — due to budget constraints, Townsend says. Those three satellites remain in service but are well beyond their design lives, and no replacements are planned. Terra, which collects data about Earth's changing climate, is the oldest of the trio and turns 15 in December.

One factor that may help Europe complete the Sentinels is that its policymakers agree on the need to stem climate change. The United States lacks such consensus.

"Simply put, Democrats tend to believe that climate change is real and Republicans tend to question it," Townsend says. "Maybe after 20-plus years of continuing sea level rise, melting Arctic sea ice, extreme weather events, etc., [Europeans] are finally acknowledging the need to figure out better what the causes of global change really are and, therefore, help the policymakers make the best choices possible rather than shooting in the dark as has happened sometimes in the past."

Townsend says Europe and the United States would both benefit from a greater U.S. role in Sentinel. Europe would gain another funding source and the United States would gain more eyes in the sky. At the moment, the number of U.S. Earth-observing missions is projected to plummet from more than 20 in 2014 to six to 12 by 2020, according to a National Academy of Sciences report cited by Townsend.

"We ought to collaborate much more than what we are currently doing on the important global problem of climate change," he says. "That would help prevent unnecessary duplication of effort and help ensure the continuation of needed measurements for the future."

Leonard David contributed to this report.