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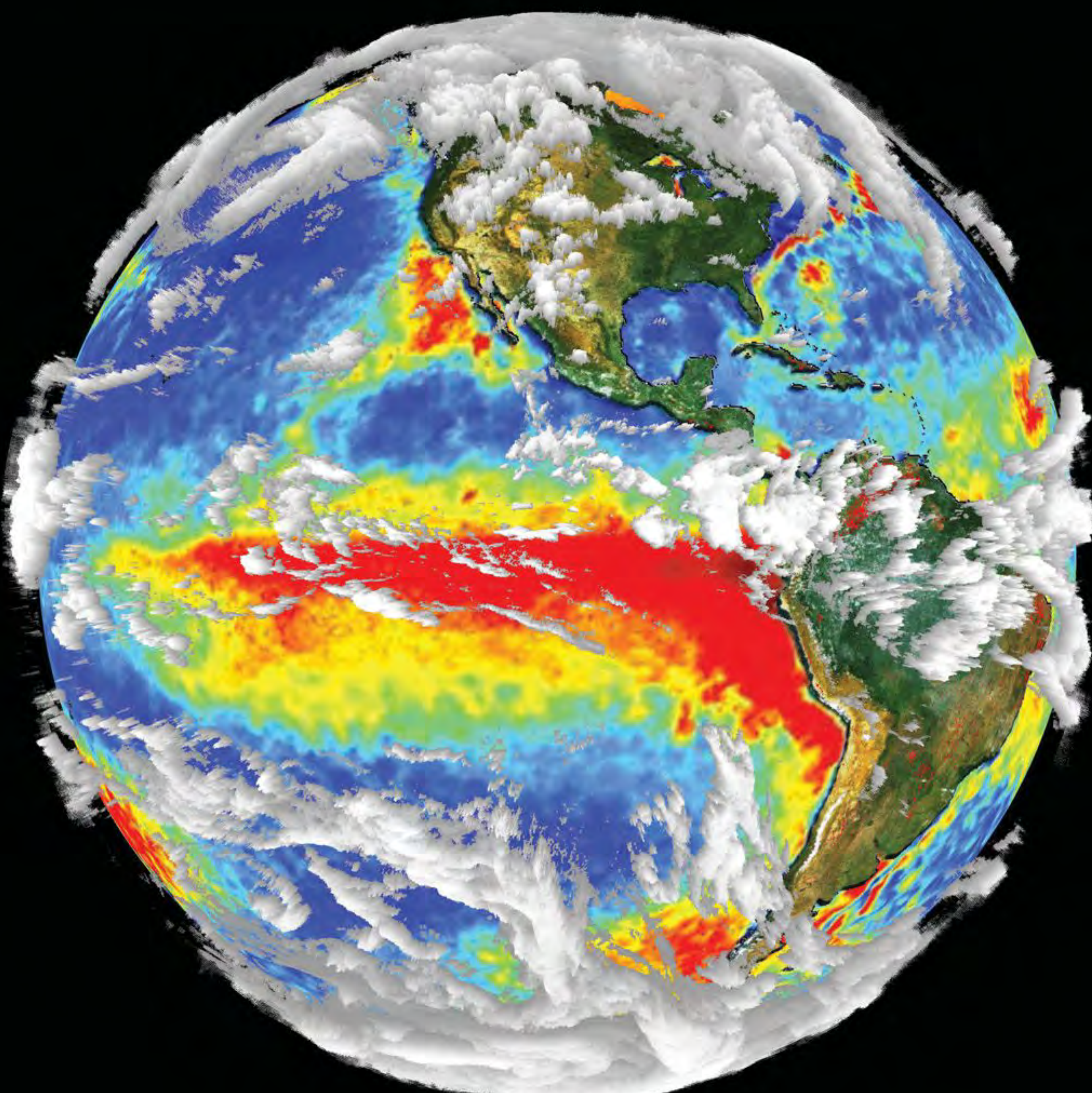
AEROSPACE AMERICA

Target: Climate change

Two satellites that could cool the debate



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TARGET:

In the next two years, NASA, in collaboration with other agencies, will launch satellites to study the concentration of carbon dioxide in the atmosphere with unprecedented detail and ensure there is no break in two decades of precise ocean level measurements from space. The question is whether these satellites can cool the political debate and set the stage for a verifiable carbon treaty.

The first Orbiting Carbon Observatory, shown on the launch pad, crashed into the Pacific Ocean after launch. Credit: NASA

CLIMATE CHANGE

February 24, 2009, was a big day for David Crisp, the principal investigator for the Orbiting Carbon Observatory mission at NASA's Jet Propulsion Laboratory in Pasadena, California. Nine years of hard work and millions of dollars spent on research and top-notch engineering were about to pay off with the launch of a satellite that was meant to revolutionize the way climate scientists measure the concentration of carbon dioxide in the atmosphere and calculate its effects on the Earth's climate. At 4:55 a.m. Eastern Standard Time, the Taurus XL rocket carrying the satellite blasted off at Vandenberg Air Force Base in California; about 3 minutes 40 seconds into the flight, Crisp and others in the control room realized there was something seriously wrong: the launch vehicle's ascent was 1 kilometer per second too slow. Crisp remembers putting his hands over his head in frustration and turning to the launch director who said simply, "I'm sorry, we failed."

"It took me a while to fully understand what it meant," says Crisp.

Seven minutes later the $273-million piece of NASA equipment re-entered and burned up in the Earth's atmosphere. "A handful of titanium parts may have made it to the surface, but that's now in the Indian Ocean or the South Pacific," Crisp says. The satellite's protective shell—the fairing—failed to separate as planned, weighing down the rocket and slowing the acceleration. "That was not my best day, to put it very mildly," says Crisp.

But even before the sun rose, Crisp's boss at the time, Earth Science Division Director Michael Freilich, told him that the mission was so important it should be replicated. The challenge would be convincing the powers that be to fund it. Crisp imagined the scenario through the eyes of those holding the purse strings: "This kid, who you knew just dropped a quarter of a billion dollars into the Pacific Ocean, walks up to you, a policy maker, and says 'Sir can I have some more?"

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After nine months of frustration and nearly giving up, in December of 2009 Crisp got an excited 2 a.m. phone call from a White House official at the Copenhagen climate summit informing him that the mission was back on. This time his team had only three years to build the satellite. In July 2014, just four years after the fiery crash at the OCO launch, NASA is poised to launch OCO-2, the original's exact replica.

OCO-2's predecessor, OCO, lifted off on a Taurus booster in February 2009. Credit: Orbital Sciences

Illusion vs. facts

Crisp is under no illusions that a success this time would usher in an era of vast, new climate-focused space investments. "We understand that we live in a finite world and there are always resource limitations. This is not the Apollo days," he says. "We need

by Natalia Mironova

The two large segments of OCO-2's fairing, or outer shell. Credit: NASA

to move forward on this, just to keep up with the changes that we're seeing in our climate system."

So, in the next two years, NASA plans to target two key factors that will figure prominently in the political debate over whether and how to combat climate change. Assuming all goes well this time, OCO-2 will map the distribution of carbon dioxide more completely than today's ground sensors can. That ability could help the U.S. verify a future carbon emissions treaty. Another satellite, called Jason-3, will bounce radar signals off the ocean to ensure scientists can measure sea surface height accurately for years to come. It's scheduled for launch in March 2015.

There's a chance the missions could help cool the political debate that has frustrated those scientists who argue that the scientific debate is largely over. "Global warming is real, it's caused by people, and you have to be pretty wacky to think otherwise," says Josh Willis, a climate scientist at NASA's Jet Propulsion Laboratory and project scientist on the Jason-3 project, an international effort to monitor ocean levels. Crisp says people who aren't scientists have the luxury of believing in "Santa Claus" if they want to, but that scientists must reach conclusions based on data. "From our measurements and our models and everything that we've been able to derive from our planet, [scientists are convinced] that CO_2 traps heat from the sun and causes the Earth to warm up a little bit."

Mysterious processes

Mostly, scientists see the role of OCO-2, in particular, as one of untangling the mystery of why Earth isn't warming even faster, given the explosion of carbon emissions in the industrial era. From an array of 150 ground sensors, scientists have a good idea of how much CO_2 is in the atmosphere. What the scientists don't know is where it all comes from, where it goes, and what

OCO-2 is designed to make global CO_2 measurements of atmospheric carbon dioxide. Credit: Orbital Sciences

processes control it. They hope the precise, global measurements from OCO-2 will shed light on the mystery of why and how the Earth's ecosystem and oceans have been consistently able to absorb half of the steadily increasing amount of carbon emitted by human activities.

"Wouldn't it be nice to know what processes are kicking into gear to do this, and maybe ask a question: Can we exploit some of those processes to pull some of the carbon dioxide out of the system? That would solve some of our problems," says Crisp.

There are some scientists who question the causes of climate change, but even they agree that the climate is changing, and that the efforts to study climate are valid and valuable. Roy Spencer, a vocal skeptic on the issue of man-made causes of global warming, serves as science team leader for one of the instruments flying on NASA's Aqua satellite, the mission dedicated to studying the Earth's water cycle. "I think our Earth observational satellites are indispensable for understanding the climate system, partly because only satellites can provide truly global coverage. The data collected in the last 10 to 30 years will be providing new research insights for decades to come," says Spencer.

According to the 2013 report by the Intergovernmental Panel on Climate Change, "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased."

Advantage of satellites

Satellite remote sensing technology is becoming the go-to tool for scientists in tracking climate change indicators such as greenhouse gases, ocean levels, ice and aerosols, by allowing the scientists not only to look at the Earth as a whole, but also to take extremely accurate readings from parts of the globe previously too inaccessible to measure. As a recent paper in the scientific journal Nature concludes, satellite remote sensing "has provided major advances in understanding the climate system and its changes" by enabling more accurate readings and better coverage than conventional observation and computer models.

Crisp says trying to measure CO_2 without satellite technology would be like relying exclusively on the ground stations of the 19th century to forecast the weather. "We need space-based measurements of carbon dioxide that are accurate enough that we can understand what processes on the surface of the Earth are emitting carbon dioxide. That includes human processes and natural processes, and what natural processes on the surface of the Earth are absorbing carbon dioxide. We need to know what, where, how, why and for how much longer these processes will operate," says Crisp.

That's the reason to go to space; and when you look at the Earth from space, you see mostly water. The ocean covers 71 percent of the Earth's surface, and it's the "best yardstick" for measuring the planet's health, according to NASA's Willis. Ninety percent of carbon released into the atmosphere gets absorbed into the ocean, warming it up and increasing its acidity, threatening some sea life. The predicted 3-foot to 5-foot level rise over the next 100 years would have huge economic impacts on communities within close proximity to the shoreline. It would be "way cheaper" to ad-

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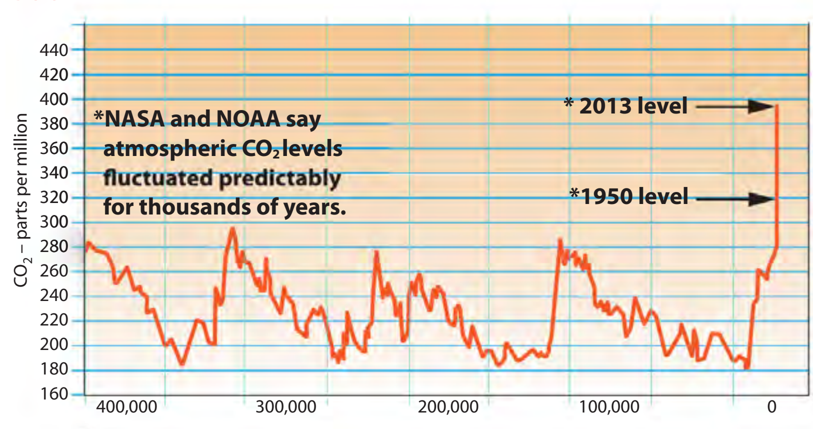
SOUNDING THE ALARM



Source: NASA/NOAA

Scientists use ice core samples to estimate CO_2 content in the ancient atmosphere, and 150 ground-based atmospheric stations to chronicle modern CO_2 levels. The Orbiting Climate Observatory satellite will fill gaps in this ground-based data by collecting CO_2 measurements at fine spatial resolutions over the globe.

Technicians prep the OCO-2 instrument for shipping. Credit: NASA/JPL-Caltech

dress climate change now than "to rebuild all our infrastructure and pull back from the sea as it advances," says Willis.

Jason and GOSAT

NASA has been using remote satellite sensors to observe the oceans since 1992. The original purpose of the mission called Topex Poseidon was ocean topography—to map the surface of the ocean and to study its currents. Two satellites followed the Topex Poseidon mission—Jason-1 and Jason-2. As scientists began to look at sea level rise as an indicator of climate change, the Jason team began to shift focus to monitoring sea level and temperature.

Jason-3 is the newest incarnation of this mission. It's an international mission led by NOAA and EUMETSAT (the European Union's equivalent of NOAA's satellite program) in collaboration with NASA and the French Space Agency CNES. The agencies are working closely together: NASA's Jet Propulsion Laboratory is providing some of the sensors that will be placed on the satellite frame or bus being built by the French; the French are also building the primary instrument, the altimeter. The technology behind the mission is surprisingly simple, according to Willis. To measure the distance between the satellite and the ocean's surface, Jason-3 and its predecessors carry altimeters that bounce radar waves off the surface and measure how long it takes the reflected signals to come back. Another instrument on board, called a radiometer, measures the concentration of water vapor to correct the measurement. A three-part location-finding system pinpoints the satellite's position at any given time. "And the difference is how tall the ocean is. It's pretty simple, really," says Willis.

Jason-3 measures the height of the ocean surface. Credit: NASA/JPL-Caltech

The three NASA-built instruments—the microwave radiometer and two location-finding instruments—the GPS and the laser-reflector, along with associated ground support equipment, were shipped to France in May. They will be installed on the Jason-3 satellite along with the altimeter and the "reverse GPS"—another positioning sensor. They'll be tested before being dispatched back to Vandenberg Air Force Base in California for the 2015 launch on a SpaceX Falcon 9.

Close international collaboration is required for space-based climate monitoring. According to John Bates, chief of the remote sensing division at NOAA's National Climatic Data Center, countries have been working together and sharing resources since the early days of weather satellites. "If all our assets are down, we can count on our international satellites. There is great international collaboration in Earth conservation right now," says Bates.

In fact, when the OCO mission crashed during launch in 2009, the Japanese scientists who just a month earlier launched GOSAT—their version of a CO_2 monitoring satellite—reached out to NASA's Crisp and his team and suggested they work together. "We didn't want to be the man with two watches who didn't know what time it was, so we started working together in 2004," says Crisp. "My Japanese colleagues said, don't waste all this effort you put into this as a science experiment, your science team is some of the best people in the world, come work with us, and we'll make use of this great progress we made together." The GOSAT team provided the NASA scientists on the OCO team with measurements they could use to continue their research as they worked to put their own satellite into orbit. Crisp is grateful for GOSAT's contribution. Still, he is excited to improve on its technology—the OCO-2 will take 100 times as many usable measurements daily as GOSAT.

Treaty monitoring

Crisp is convinced that President Obama's trip to the Climate Summit in Copenhagen in December of 2009 was the catalyst to reviving the OCO mission. Having an accurate CO_2 monitoring satellite in space would potentially give the United States the data it needs to work with other countries on reducing carbon emissions and to have the background for a carbon treaty it will sign in the future. Crisp points out that the OCO-2 was not designed for carbon treaty monitoring, but its innovative approach has the potential to measure CO_2 emissions in the now poorly measured developing world, expanding the treaty to include more nations.

"It gave us the opportunity to monitor a possible CO_2 treaty from space and to verify the results of ground-based work that otherwise could not be verified. And that's one of the sticking points that came out of Copenhagen: Nobody wanted on-site inspections. And so things like OCO and OCO-2 and maybe its follow-on may be critical for verifying any future carbon dioxide treaty that our country signs. In fact, having those measurements in place and understanding what we can learn from them may be a precursor to any greenhouse gas treaty the U.S. wants to sign. Because why sign a treaty if you can't verify it?" says Crisp.

When OCO-2 is launched this year, it will carry aboard the technologies that were originally developed for ground-based astronomy and studying other planets. JPL scientists then modified these components to measure clouds in Earth's atmosphere and the concentration of carbon dioxide.

The OCO-2 instrument is a three-channel spectrometer that divides the sunlight into a rainbow of colors and isolates three "absorption bands" in the near infrared, just beyond what the eye can see, where CO_2 molecules and oxygen molecules are most visible and the scientists are able to count them. "We make that measurement very precisely, to three-tenths of 1 percent. This is an incredibly difficult measurement to make using remote sensing," says Crisp. He explains that the same basic technology is used by other agencies around the world that are employing or planning to launch their own CO_2 monitoring satellites. "All will launch the same basic technique that we pioneered in 2000. Different instruments, but we pioneered that track, we told them how to do it," Crisp says.

All these satellites will eventually work together to provide the most accurate global picture of CO_2 distribution, its sources and sinks.

The main culprit

So what makes CO_2 monitoring so critical that the U.S. Congress, the current administration and many governments around the world, including China, Japan and the European Union, are investing resources into research and continuing monitoring from space? Carbon dioxide is not the only heat-trapping greenhouse gas, but it's notable because its concentration has increased dramatically since the dawn of the industrial age – from an average of 270 parts per million to nearly 400 parts per million. According to NASA's Crisp, it's a "big change." Climate scientists zero in on carbon dioxide because they believe it's the main culprit responsible for global warming, but also because there is still so much to learn about the natural processes on Earth that control the balance of CO_2 production and emission. The oceans and the land's biosphere naturally "breathe out" CO_2, but they are actually absorbing more than they are emitting each year. "We now know that the natural processes are absorbing half of all the carbon dioxide that's being emitted by human processes, such as burning fossil fuels and land use practices. What processes are responsible for absorbing half of our carbon dioxide emissions? We don't know," Crisp says.

Crisp and his OCO-2 team hope to shed light on some of these mysteries once they begin delivering data to the scientific community at the end of 2014, and he views his mission as critical to the planet's well-being: "Earth scientists, whether we're working on the ground, in aircraft or on satellites, are diagnostic physicians trying to understand the health of the system we live in. It's crucially important."

OCO-2 is scheduled for launch in July. Credit: NASA/JPL

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Roy Spencer, climatologist