

NASA & the Navy Developing the Fuel of the Future

Joint Effort Investigating Algae Farms in the Ocean

IN FEBRUARY 2011, the National Aeronautics and Space Administration (NASA) signed a Memorandum of Agreement (MOA) with the Navy to test a system for producing what many believe to be the fuel of the future, using algae grown in the ocean.

“Changing the way energy is used and produced in our country is the right thing to do,” said Navy Secretary Ray Mabus, upon signing the agreement. “It’s the right thing to do for

in sediments. Under some conditions, with appropriate temperatures, pressures, and rock formations, they form oil that accumulates in reservoirs. Once discovered, these reservoirs can be tapped to meet our fossil fuel needs.

Fortunately, plants living today can also produce oil. For example, 50 gallons of fuel oil can be produced per year from an acre of soybeans, and 600 gallons can be produced from an acre of palm trees. The plants that produce the most

oil. On 22 April, Earth Day, 2010, the Navy flew an F/A-18 Super Hornet fighter jet at Mach 1.2, powered by a blend of conventional jet fuel and alternative aviation biofuel made from camelina oil. More recently, the Navy tested its RCB-X combat boat on a blend of conventional diesel and algae biodiesel, and flew an SH-60 helicopter on a similar blend. The important conclusion is that biofuels work—they function without re-designing engines and equipment.

Changing the way energy is used and produced in our country is the right thing to do.

—Navy Secretary Ray Mabus

our security, it’s the right thing to do for our economy, and it’s the right thing to do for our environment.”

The Basics About Oil

The oil we use today comes from plants that lived in ancient times—mostly microscopic, single-celled, plants called microalgae, which lived in seas and lakes. When they died, they settled to the bottom and were buried

oil, however, are the modern versions of the microalgae that made most of our fossil oil. From among the thousands of known types of microalgae, researchers have discovered some species that can support production of between 2,000 and 5,000 gallons of oil per acre per year.

The Navy has taken the lead in demonstrating that it is possible to make functional fuel out of vegetable

The next questions are, how do we produce enough of this fuel to meet our needs? How do we produce biofuels economically? How do we produce them without competing with agriculture for land, water, and fertilizer?

Transform Wastelands into Fuel Farms?

The Navy is testing fuels like camelina and algae because they are not food

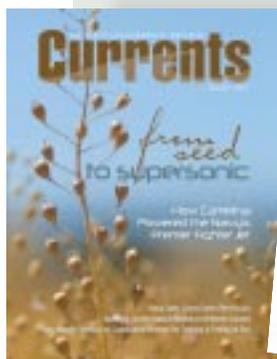


Prototype OMEGA photobioreactors being deployed in seawater tanks to grow microalgae on wastewater from the nearby sewage treatment plant.
 URS Corporation

crops and their production will not compete directly with agriculture. In this regard, microalgae is a superb potential source of biofuels, because it produces the most oil, it grows in water, and marine algae can even grow in seawater. At present, microalgae are commonly grown in shallow circulating channels called “raceways” or in transparent enclosures known as photobioreactors (PBR). To produce biofuels, thousands of acres of raceways and tens of thousands of PBRs will be required. In principle, to avoid competing with agriculture for land, raceways and PBRs can be located in deserts or on unusable fallow land. For water, they can use seawater and cultivate oil-producing marine algae.

For More Information

FOR MORE INFORMATION about the RCB-X demonstration, see our article entitled “Navy Fuels Great Green Fleet Vision: Latest Milestone on the Road to Energy Security” in the winter 2011 issue of *Currents*. For more insights into the Navy’s success in flying an SH-60 helicopter on a blend of conventional and algae biodiesel blend, see our article entitled “Navy Tests New Fuel in Seahawk Helicopter: Demo Provides “Off Ramp” from Petroleum-Based Fuels” on page 16 of this issue of *Currents*.





Open ponds, also called "raceways" are one of the traditional methods for cultivating microalgae. This method is subject to evaporation issues.

Cyanotech

It is estimated that replacing the evaporated water in these systems and maintaining appropriate salinities for most algae would require trillions of gallons of freshwater per year.

For fertilizer, they can use domestic wastewater from cities. This seems like a reasonable solution to our fuel challenge; however, there are a couple of problems with this scenario.

The Devil is in the Details

The primary reasons that there are not yet large-scale algae fuel farms in the desert are logistics and economics. If raceways or PBRs are installed in deserts, they would usually be far away from the coast and from major cities. Substantial costs would be involved in transporting the required seawater and domestic wastewater long distances to the desert installations. While it is possible to pump or ship water from one place to another,

this requires significant amounts of energy, which makes the final product more expensive.

With open-air raceways, evaporation is a problem, resulting in an increased need for freshwater. It is estimated that replacing the evaporated water in these systems and maintaining appropriate salinities for most algae would require trillions of gallons of freshwater per year.¹ There is obviously little water in the desert. Transporting water is expensive, and the use of that much water could seriously compete with agriculture and impact our finite supply of a basic resource.

Evaporation is not a problem for PBR systems because they are

closed and sealed. But algae require sunlight for photosynthesis; and where there is sunlight, there is heat. Putting heat into a sealed chamber containing water raises the water temperature, and most species of algae die in hot water. Therefore, to maintain temperatures suitable for growing algae, PBRs need to be cooled. It is possible to spray the outside of the PBRs with freshwater and use evaporative cooling, but this technique creates another water use problem.

These considerations and other challenges have led to the conclusion that despite the great potential of microalgae, at least a decade may be required to produce significant

quantities of biofuels using traditional raceways or PBRs.¹ The question then arises—is there another process that can be developed more quickly to grow the large quantities of oil-producing microalgae that the United States needs?

The OMEGA System

The Navy is teaming up with NASA to investigate a radical new approach to large-scale algae cultivation using a system called Offshore Membrane Enclosures for Growing Algae (OMEGA). The OMEGA system consists of floating PBRs filled with wastewater from existing offshore sewage outfalls and deployed in protected marine environments. The

individual OMEGA modules are constructed of flexible plastic, clear on top, to allow light penetration for photosynthesis, and reinforced white plastic on the bottom, for strength. The modules are filled with secondary-treated wastewater and inoculated with freshwater algae. If the system leaks, it minimally impacts the environment because:

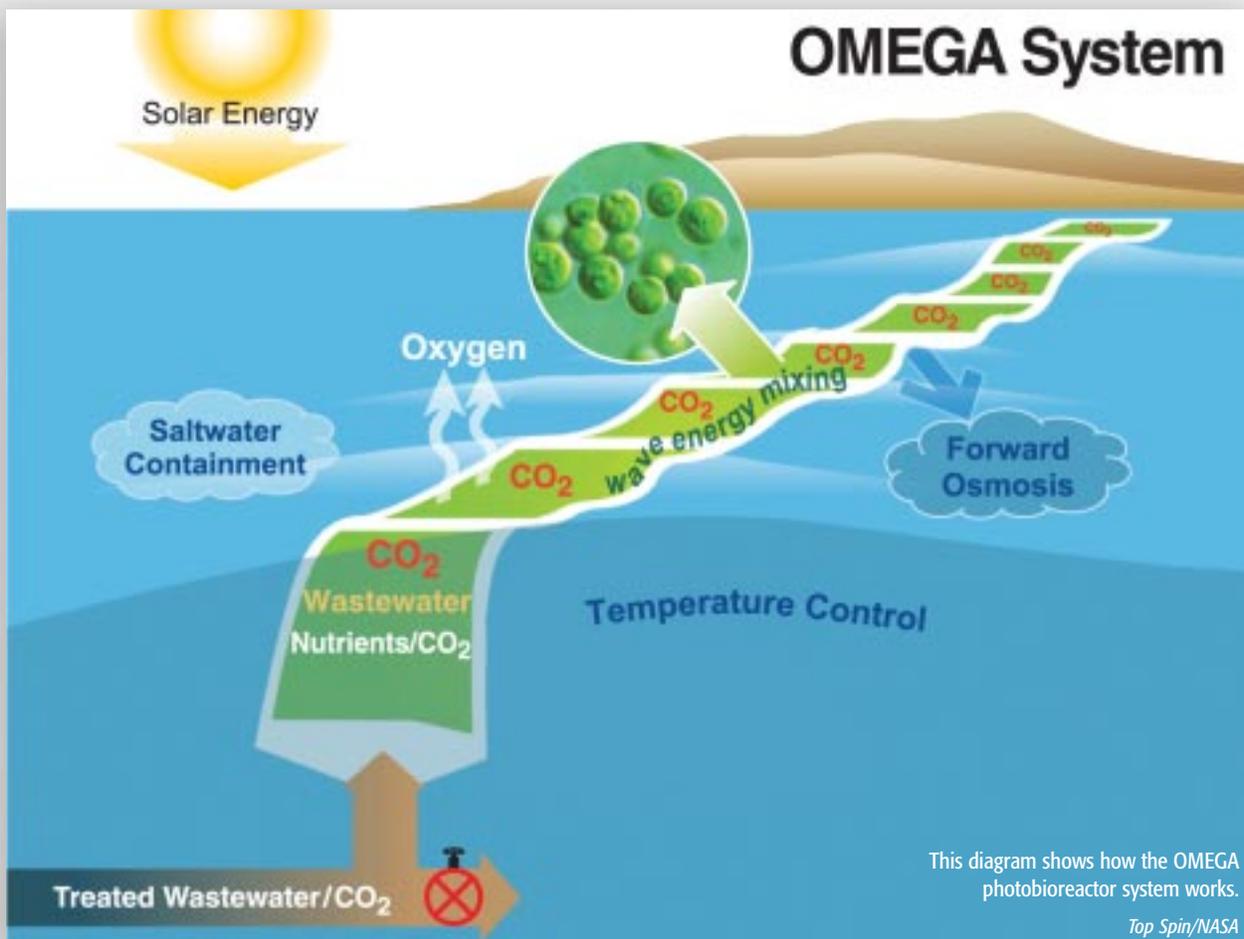
1. The wastewater is already approved for release into the ocean
2. The freshwater algae cannot survive in seawater

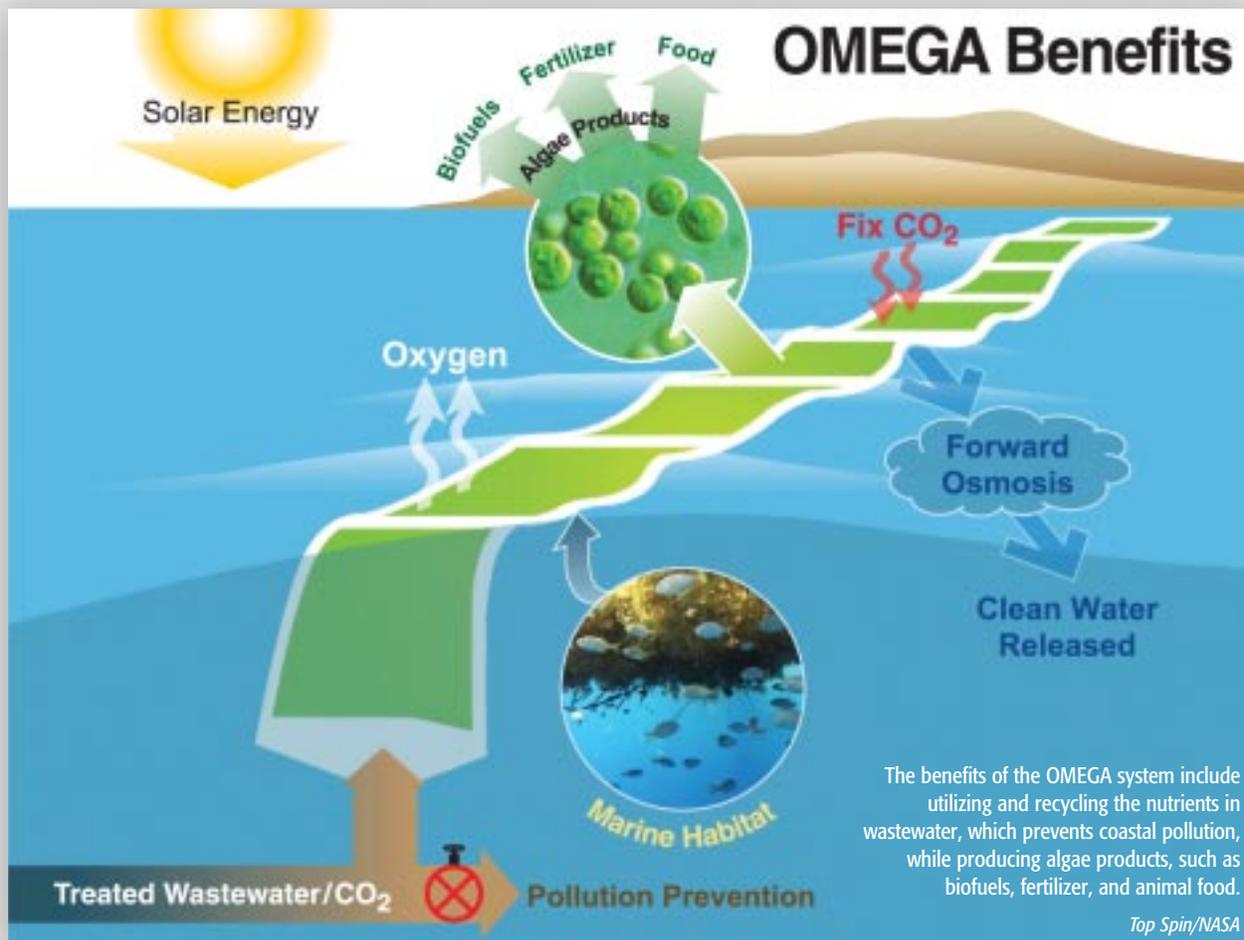
OMEGA utilizes virtually nothing except natural energy—solar energy to initiate photosynthesis and wave energy to maximize algae exposure

to sunlight and to mix nutrients. Unlike land-based PBRs that can overheat, OMEGA uses the surrounding water for temperature control. It uses the salinity difference between wastewater and seawater both to prevent algae that escape from becoming invasive species and to drive forward osmosis (FO).

Forward osmosis is the process by which water moves across a selective semi-permeable membrane in the direction of concentrated salts. The OMEGA system uses FO to:

1. Concentrate nutrients in the wastewater, stimulating algae growth
2. Dewater the algae, facilitating harvesting





The challenges and rigor of space travel led NASA to design and develop equipment and life-support systems that optimize the use of resources, minimize the use of energy, and recycle, refurbish, and reuse everything.

- Clean the wastewater released into the surrounding environment

It will be sensible to build first generation OMEGA farms in protected bays, in areas surrounded by breakwaters, or in places with existing marine infrastructure; such as offshore oil platforms or wind farms. In the vicinity of wind farms, OMEGA could use existing infrastructure and could benefit from the source of local energy for pumping water.

Why the Navy? Why NASA?

The military is the largest single user of fuels in the United States, and for the foreseeable future there will be a need to continue using liquid fuels; not only for aircraft and ships, but also for operations in remote locations. However, the danger and expense in transporting these fuels, and the dwindling reserves of fossil fuels, underscores the need for alternatives to fossil fuels.

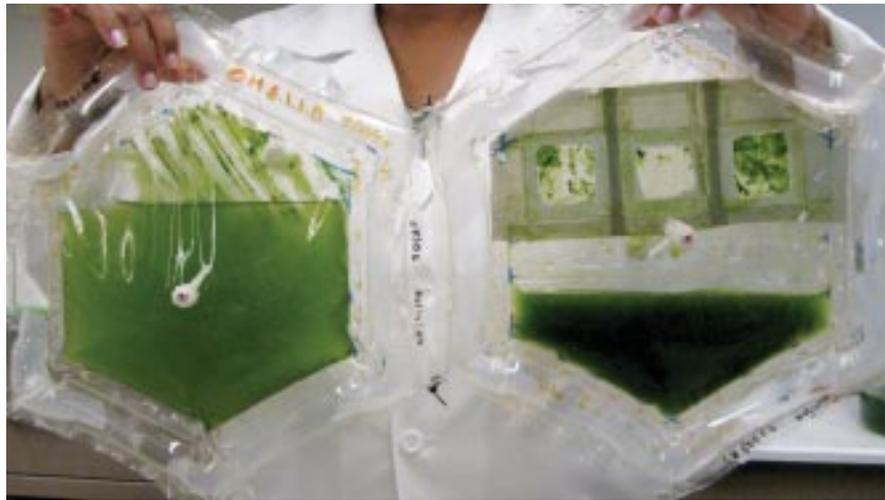
The aeronautics industry has also recognized the need for alternative fuels, but it is the technology developed for space travel that provided the foundation for the OMEGA project. The challenges and rigor of space travel led NASA to design and develop equipment and life-support systems that optimize the use of resources, minimize the use of energy, and recycle, refurbish, and reuse everything—materials that on earth are taken for granted or discarded as waste. It was with this

focus on efficiency and parsimony that OMEGA began.

The feasibility and scalability of the OMEGA system will be determined by combining NASA expertise with the knowledge and expertise of naval engineers, university professors and industry.

The State of OMEGA

Supported by the California Energy Commission and NASA's Aeronautics Research Mission Directorate, the team of NASA scientists, Navy engineers, civil engineers from URS Corporation,



Samples from two different OMEGA PBRs. After three days floating in seawater, microalgae grew in both photobioreactors, but the one with forward osmosis membranes significantly changed volume due to the loss of water into the seawater. This concentrates the microalgae.

Jonathan Trent



The inside of a PBR. PBRs are one of two ways that algae is farmed on land.

John Benemann

I don't want us to be remembered as the generation of locusts, who consumed everything and left nothing for future generations. I'd much rather have us be known as the "regeneration generation."

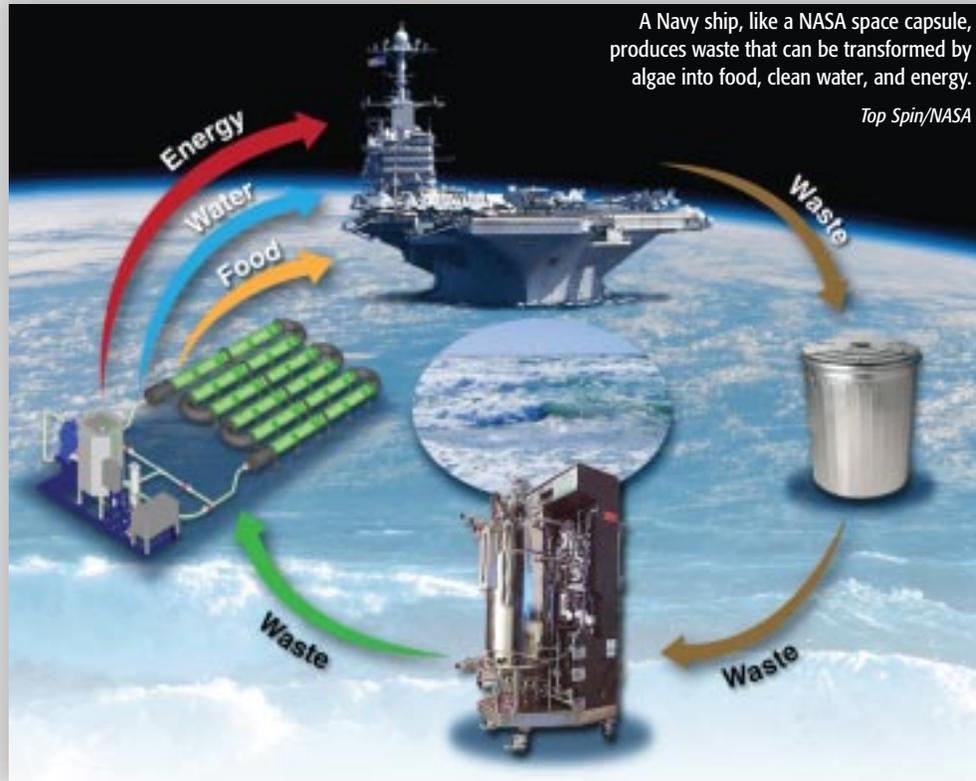
—Rear Admiral Phillip Cullom

and algae experts from the University of California at Santa Cruz, are building small-scale OMEGA PBRs in California. Floating these PBRs in seawater tanks, they are determining operating conditions for growing algae and treating wastewater. Naval engineers, using tow tanks and wave tanks, will determine how an OMEGA system will ultimately fare in the marine environment. These studies will guide the further development of durable PBR designs that can withstand the rigors of the marine environment, while providing information about the energy return on investment and the feasibility of commercializing OMEGA systems.

If successful, the project has the potential to help the Navy reach its goal of finding an alternative to fossil fuels, energy independence and a more sustainable future. Rear Admiral Phillip Cullom said in a recent lecture: "I don't want us to be remembered as the generation of locusts, who consumed everything and left nothing for future generations. I'd much rather have us be known as the 'regeneration generation.'"¹ [↓](#)

¹ Ronald Pate. 2007. *Techno-economics, Siting and Resource Use Challenges for Onshore Algal Biofuels Production*, Wind, Sea Algae Proceedings. <http://wind-sea-algae.org?page.id=305>.

² RADM Phillip Cullom, October 2010. Keynote lecture at a meeting of the Algae Biomass Organization, Phoenix, AZ.



A Navy ship, like a NASA space capsule, produces waste that can be transformed by algae into food, clean water, and energy.

Top Spin/NASA

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