TITANIUM NEWS

A concise and timely report on Titanium and Titanium Recycling

SIMS Metal Management Aerospace

Beautiful Titanium

MANUFACTURERS OF FINE RECYCLED TITANIUM PRODUCTS

INTERNATIONAL TITANIUM ASSOCIATION MEMBER

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Lockheed Martin Introduces Titanium Exoskeleton for Soldiers

The Human Universal Load Carrier (HULC) exoskeleton is not quite a robot. It is more like the legs of a robot attached to the legs of a real soldier, enhancing his strength and endurance. Designed by Lockheed Martin Missile and Fire Control engineers, the lower-body exoskeleton will enable a soldier to lift and carry as much as 200 pounds by transferring the weight to the ground through titanium legs powered by batteries. Titanium's strength to weight ratio makes it the ideal choice for metal.

Because it is attached to the outside of the leg, the HULC moves with the soldier, allowing deep squats, upper-body lifts, even crawls. An onboard microcomputer system helps to ensure that it moves with the soldier.

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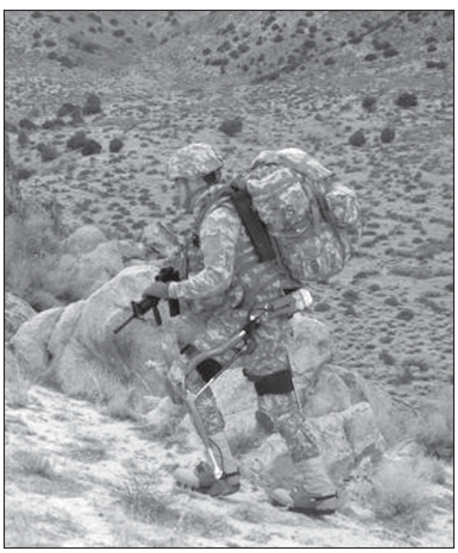
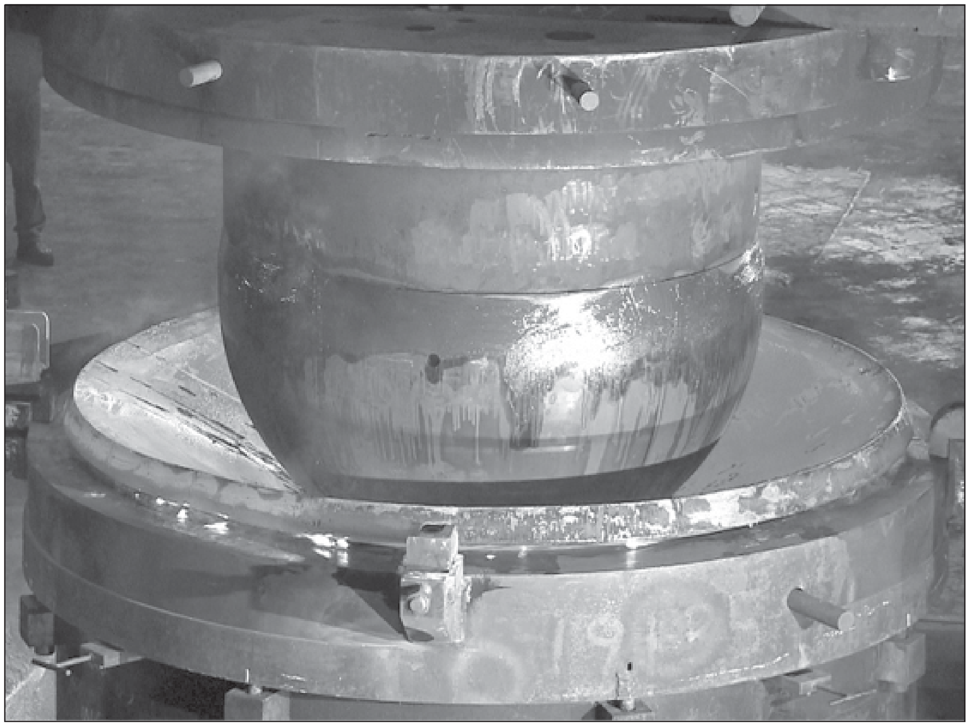


The Human Universal Load Carrier is a titanium exoskeleton that is attached to the outside of a soldier's leg, transferring the weight from heavy loads to the ground.



PHOTOS COURTESY OF THE ADVANCED IMAGING & VISUALIZATION LABORATORY, WHOI

Placed on a ring die, one of the titanium discs begins the process of being shaped into a hemisphere at Ladish Forging.

New Titanium HOV Sphere Prepares for Descent to the Deep Ocean

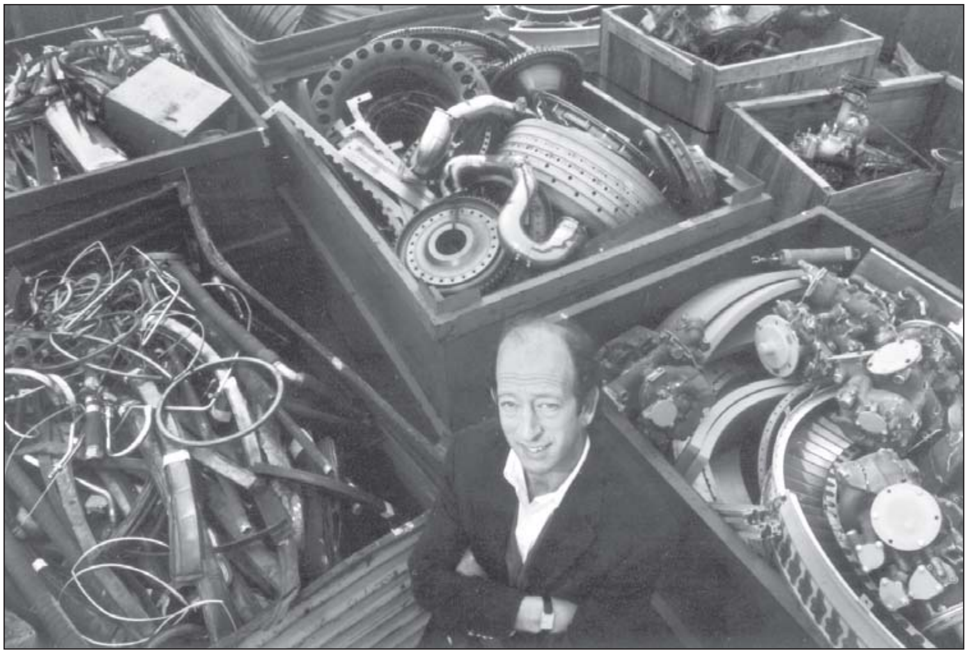
When the new Human Occupied Vehicle (HOV) that is to replace the *Alvin* finally reaches an ocean depth of 6,500 meters (4.04 miles), Southwest Research Institute®, TIMET, Ladish Forging, Bodycote Heat Treatments, and STADCO, Inc. will all have played important roles in helping it successfully reach bottom.

"The titanium sphere is definitely the biggest technical challenge to designing and constructing a new HOV," said Anthony Tarantino, a former *Alvin* pilot who is Assistant Project Manager at Woods Hole Oceanographic Institute (WHOI). WHOI manages the National Deep Sub-

(Continued on page 4)

Special Edition

48th INTERNATIONAL PARIS AIR SHOW | LE BOURGET JUNE 15-21, 2009



"We need more space," said James M. Nathan, President of Sims Metal Management Aerospace, as he stood amidst scrap metal. "The new facility will enable us to have all of our operations under one roof. It will be a state-of-the-art, green and lean super-alloy processing center."

Sims Metal Management Aerospace Breaks Ground in Hartford, Connecticut

Ground was broken in March 2009 on the new recycling facility for Sims Metal Management Aerospace in Hartford, Connecticut. The new 425,000 square-foot plant is located at 239 West Service Road. The company administrative staff will move to the refurbished section of the facility in September 2009. The move of the recycling operations into the new section now under construction will be staged throughout 2010.

Titanium Drivers Affect Hearing

Amateur golfers may have more to worry about than sand traps, trees, tall grass, and variable wind when hitting their balls down the fairway. Besides the decibels generated by playing partners shouting "fore" in their ears, golfers may be threatened by hearing loss caused by their thin-faced titanium drivers. One golfer likened the sound to a sonic boom.

Recently a team of British doctors tested the sound generated by stainless steel and titanium clubs. They determined that the sound generated by the titanium clubs was far louder. In fact, the sound of the club hitting the ball could be as loud as 120 decibels, depending on the manufacturer and model. According to Dr. Malcolm Buchanan, the results showed that the sound may induce temporary or even permanent cochlear damage in susceptible individuals. Dr. Buchanan is a golfer as well as an eye-ear-nose-and-throat specialist.

The sound is created by the coefficient of restitution (COR) which is a velocity ratio before and after impact. This is exacerbated by titanium's low damping capacity, meaning its ability to absorb vibration.

The results were reported in the December 17, 2008, issue of the *British Medical Journal*. It will probably not result in amateur golfers putting away their titanium drivers, but perhaps they might consider putting cotton in their ears before they tee off. Ti

Exoskeleton

(continued from page 1)

The exoskeleton is expected to provide a combat advantage in ground operations, ameliorating the physical stress and fatigue experienced by soldiers who must frequently carry heavy combat loads. A pack can weigh as much as 70 pounds due in part to the number of batteries soldiers must carry to power everything from radios to GPS systems and tactical computers. Battery weight can amount to 25 percent of a soldier's load. According to Jeffrey Mellinger of the Army Materiel Command, an exoskeleton capable of supporting such loads would be of great benefit.

The HULC was introduced in March 2009 at the winter symposium of the Association of the U.S. Army in Fort Lauderdale, Florida. Lockheed Martin will develop the HULC under an exclusive licensing agreement with Berkeley Bionics, provider of exoskeleton technologies. Ti

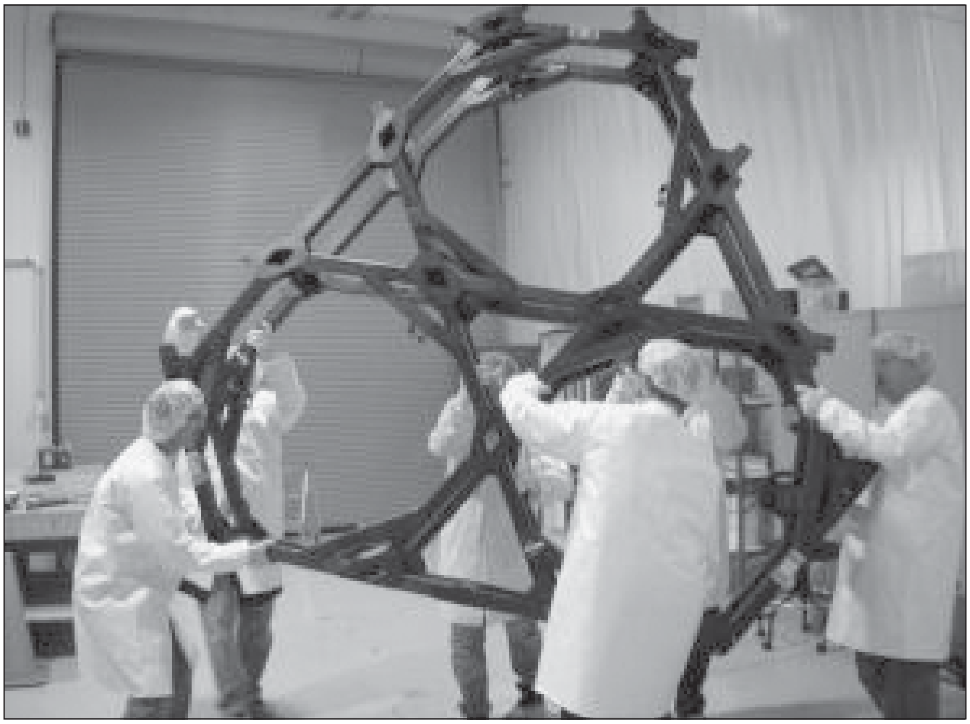


PHOTO NORTHROP GRUMMAN

Scientists and engineers at Northrop Grumman work with the Backplane Structure Test Article (BSTA) or "spine," which is made of advanced graphite composite material mated to titanium and invar fittings and interfaces. The BSTA is only 1/6 the size of the backplane that will fly in the James Webb Space Telescope.

A Titanium Spine for a Space Telescope

Alliant Techsystems (ATK) has started to assemble the Primary Mirror Backplane Support Structure, or spine, of NASA's James Webb Space Telescope at its Magna, Utah, facility. The telescope will become NASA's premier observatory following its launch in 2013, serving astronomers worldwide in their mission to investigate the formation and evolution of planets, stars, galaxies, and the early universe.

Made with advanced graphite composite material mated to titanium and invar fittings and interfaces, some 9,000 joints must be individually injection-bonded to complete the backplane. (Invar is a nickel-steel alloy with a low coefficient of thermal expansion.) ATK will deliver the backplane to Northrop Grumman in late 2010 for integration into the telescope, which is as large as a two-story house. ATK is under contract to Northrop Grumman for the engineering, design, fabrication, and testing of the Webb Telescope's composite components and subsystems.

The 2,200-pound backplane will support the telescope's 21-foot diameter primary mirror in orbit nearly a million miles from Earth. The structure is designed for unprecedented thermal dimensional stability performance and is capable of withstanding temperatures as cold as minus 400 degrees F, ensuring essentially motionless operations for optimal deep space imaging. The backplane will also carry 7,500 pounds of telescope optics and instruments during launch.

"ATK's backplane is the first time a composite structure will be used to support an astronomical segmented mirror in space, making it an integral part of the telescope's primary mirror and requiring unprecedented dimensional stability performance, at a threefold increase in size," said Kelly Franklin, Vice President and General Manager of ATK Government Space.

While the Hubble Space Telescope has captured mainly visible light images, the Webb Telescope will primarily observe light from faint and very distant objects, using instruments designed to work primarily in the infrared range of the electromagnetic spectrum. "The Webb telescope's ultimate ability to discover the first stars and galaxies is critically dependent on the mirror backplane performing to fantastically demanding standards," said Eric Smith, Webb Telescope program scientist at NASA Headquarters.

NASA's Goddard Space Flight Center in Greenbelt, Md., is managing the overall development of the Webb telescope, which is a joint project of NASA and many U.S. partners, the European Space Agency and the Canadian Space Agency. (For more information, see www.nasa.gov and http://atk.mediaroom.com) Ti

Moulton Becomes ATI Vice President

Kevin Cain Takes over at Uniti LLC

Allegheny Technologies Inc. announced in January 2009 that Carl R. Moulton had become Vice President, International. Previously Moulton had been president of Uniti LLC, ATI's titanium joint venture. In his place, Kevin J. Cain was named president of Uniti LLC.

"As President of our Uniti titanium joint venture, Carl Moulton has helped enable ATI to become more globally focused and has helped expand our direct international sales," said L. Patrick Hassey, Chairman, President and Chief Executive Officer. Mr. Moulton will be responsible for ATI's commercial activities in Europe and Asia, and ATI's STALL Precision Rolled Strip®.

A graduate of Dartmouth College, Mr. Moulton began his career as a sales representative with Allegheny Ludlum in 1972 before joining Jessop Steel as marketing vice president in 1981. He was president of Jessop Steel when it was acquired by ATI in 1993. He has served in various important commercial and strategic roles, including Assistant Vice President - Strategic Initiatives. He became the first president of Uniti in 2003.

Kevin Cain is a graduate of West Virginia University with an MBA from Drexel University. His career includes high level sales positions at Jessop Steel, TIMET, and Dynamet before joining Uniti as North America Sales Manager upon its formation in 2003. He was promoted to General Manager of Sales in 2005 assuming responsibility for Uniti's commercial activities in Asia in addition to North America. He became Uniti's Vice President, Commercial, in 2007 in which position he has been responsible for Uniti's world-wide sales and marketing. Ti

Russia and Airbus Sign Contract

In April 2009, Airbus, the aircraft maker owned by EADS NV, signed a $4 billion deal with VSMPO-Avisma, the world's largest titanium producer. VSMPO-Avisma is part of the state holding company Russian Technologies. Russian Prime Minister Vladimir Putin announced at the document signing that the contract was valid through 2020. "Our company will satisfy 60 percent of Airbus's demand for titanium," he said. VSMPO-Avisma exports 70% of its products with the remainder supplied to the domestic market. Ti

PHOTO COURTESY OF WHOI

Anthony Tarantino, a former Alvin *pilot who is Assistant Project Manager at WHOI, holds a model of the HOV sphere.*

Ti Sphere *(continued from page 1)*

mergence Facility (NDSF), a federally funded center that operates, maintains, and coordinates the use of deep-sea exploration vehicles.

A sphere has no edges, making it the most efficient shape to distribute pressure on deep-submersibles. The pressure of the water on a hull increases by 44.5 pounds per square inch with every 100 feet that a submarine descends. Therefore, the new titanium sphere must meet the highest standards for strength and fracture toughness while also being weldable without cracking. At 6,500 meters, the new HOV will be subjected to five tons of pressure per square inch, making superior titanium crystallographic texture of critical importance.

The sphere's interior will be nearly seven feet in diameter with its wall being nearly three inches thick. *(Alvin's* present sphere is six feet in diameter and its wall is two inches thick.) Its volume will be 23 percent larger, allowing more space for scientific equipment and more room for crew. However, not until the completion of the second phase of construction (scheduled for 2015, depending on funding availability) will the new HOV be able to descend to 6,500 meters. The current *Alvin* can only reach 4,500 meters (2.8 miles).

The Design

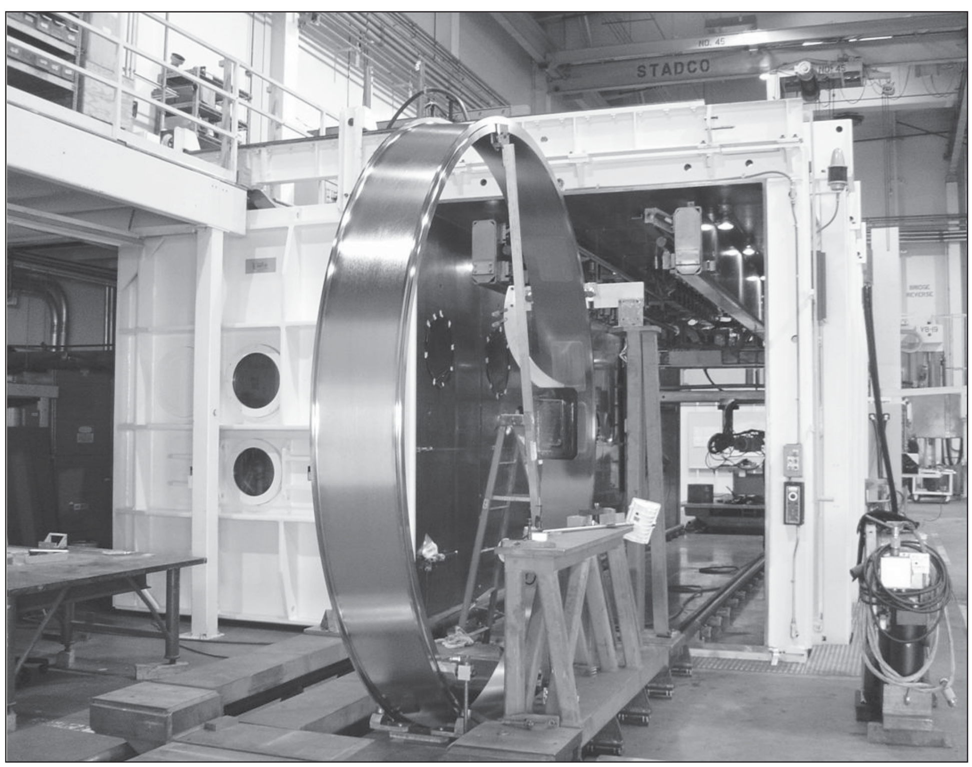
Southwest Research Institute (SwRI®), San Antonio, Texas, was awarded the contract in 2006 to design, fabricate, test and deliver the pressure hull. SwRI has over 40 years of history successfully designing, building and testing manned and unmanned deep-submersibles. In fact, it has recently designed a new submarine crew rescue hull for the U.S. Navy using HY-100.

One of the sizable challenges SwRI faced was minimizing the pressure hull's weight and increasing its size. Above all, it must be qualified for operations at 6,500 meters. Another factor was that the new HOV could not be much larger or heavier than the present *Alvin* because it must be compatible with existing launch systems and storage hangar size on the *Alvin's* 274-foot research vessel *Atlantis.* Physical size and weight affect every aspect of the HOV's design, including the batteries (which are expected to be lithium ion instead of lead acid), the variable ballast system, and the science payload capacity (181 kg, up from the *Alvin's* 125 kg).

Another issue for SwRI was which titanium alloy to use. The spheres of the *Alvin* and U.S. Navy's *Sea Cliff* are composed of an uncommon titanium alloy developed by RMI and the U.S. Navy, Ti-6Al-2Cb-1Ta-1Mo (no longer available). Having years of titanium alloy design and fabrication experience, SwRI chose to use Ti-6Al-4V ELI which has high fracture toughness. Because of its low oxygen content, risks associated with stress corrosion cracking are reduced.

Forging the Ingots

Work began in earnest in the spring of 2008 when the three Ti-6Al-4V ELI ingots were produced by Titanium Hearth Technologies (part of TIMET), Morgantown, PA, using EB Vacuum Arc Remelting (VAR). The two ingots to be used for the hemispheres were 11,000 pounds each. The third ingot to be used for the viewports and hatch was 7,000 pounds.



STADCO's EB machine is one of the largest in the world. The EB gun is mounted on a 5-axis head that can operate at 42 KW power levels.

PHOTO COURTESY OF B.K. MILLER, SwRI

Matt James, senior research engineer at Southwest Research Institute, stands amidst the three titanium ingots at Titanium Hearth Technologies, Morgantown, Penn. The two 11,000-pound ingots are for the hemispheres and the one 7,000-pound ingot is for the viewport and hatch inserts.

The ingots were shipped to Ladish Forging in Cudahy, Wisc., where in the summer of 2008, its huge No. 154 press began to shape the eleven-foot discs. "Fortunately, Ladish has a great deal of experience with forging unusual shapes because of our work with large solid rocket motor components," said Douglas Roberts, General Manager, Sales & Marketing for Ladish. "We forged the Titan rocket motor steel forward and aft domes which were 120 inches in diameter, so forging the HOV's two hemispheres was definitely within our expertise and equipment capability. The unique challenge was forging this component from 6-4 titanium."

"To achieve a uniformly refined alpha-beta microstructure in the final product required designing a creative forging sequence for the ingots," explained Thomas Furman, a senior engineer at Ladish. "Each 11,000 pound ingot was forged by upsetting and drawing – also known as cogging – and then doing it repeatedly to achieve the desired refinement. Drawing extremely large pieces of titanium often causes them to become so tall that they can buckle during upsetting. Ti 6-4 presents temperature management challenges, so control is critical."

For homogeneous symmetry, the shapes were upset, paddled and flattened to reach an initial circular disc of approximately six inches thick. Next the discs were shaped into hemispheres.

"After hot forging, we did not pre-machine 100% prior to heat treatment," said Mr. Furman. "The forging inspection worked out so closely to the computer modeling prediction that we had the anticipated cross-sections necessary for heat-treatment."

Heat-Treating and Welding

The hemispheres were shipped to Bodycote Heat Treatments, Los Angeles, Calif., for solution treating and quenching. Upon their return to Ladish, they were rough-machined and tested (ultrasonic, fluorescent penetrant inspection, physical testing and dimensional inspection). Ladish finished its work in November 2008. "It was an amazing, history-making project," concluded Mr. Roberts.

Then it was back to Bodycote for vacuum stabilization annealing. From there the hemispheres were shipped to STADCO, Inc., Los Angeles, Calif., for special machining.

The two hemispheres are now at STADCO for final machining that will include weld preps before being joined together using EB welding, which is scheduled to commence in June, 2009. The EB welding process is performed under high vacuum levels which helps to eliminate the formation of Alpha Case which is identified as a source in initiation of cracks and fatigue issues for titanium alloys, especially the ELI grade.

With a chamber size of 362" x 108" x 132", STADCO's EB equipment is considered the largest machine in North America and one of the largest in the world. The EB gun is mounted on a 5-axis head that can operate at 42 KW power levels. This enabled STADCO to develop an ABS-approved welding process in which the electron beam will penetrate and join a five-inch thick titanium section in a single pass. This weld process also minimizes the size of the heat-affected zone, producing welds with virtually no distortion and having strengths and properties very similar to the parent material. All controls are fully NC controlled helping to make the process highly consistent and reliable.

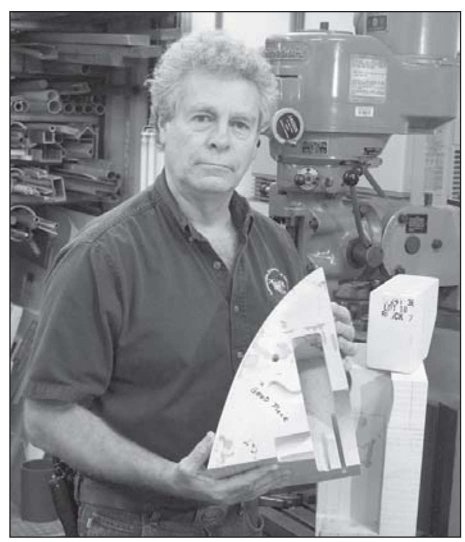


PHOTO COURTESY OF TOM KLEINDINST, WHOI

Rod Catanach, a WHOI engineer, holds a piece of syntactic foam, a matrix of billions of microscopic hollow glass spheres embedded in a hard epoxy resin. The material is strong enough to resist crushing, yet it is lighter than water, thus providing buoyancy.

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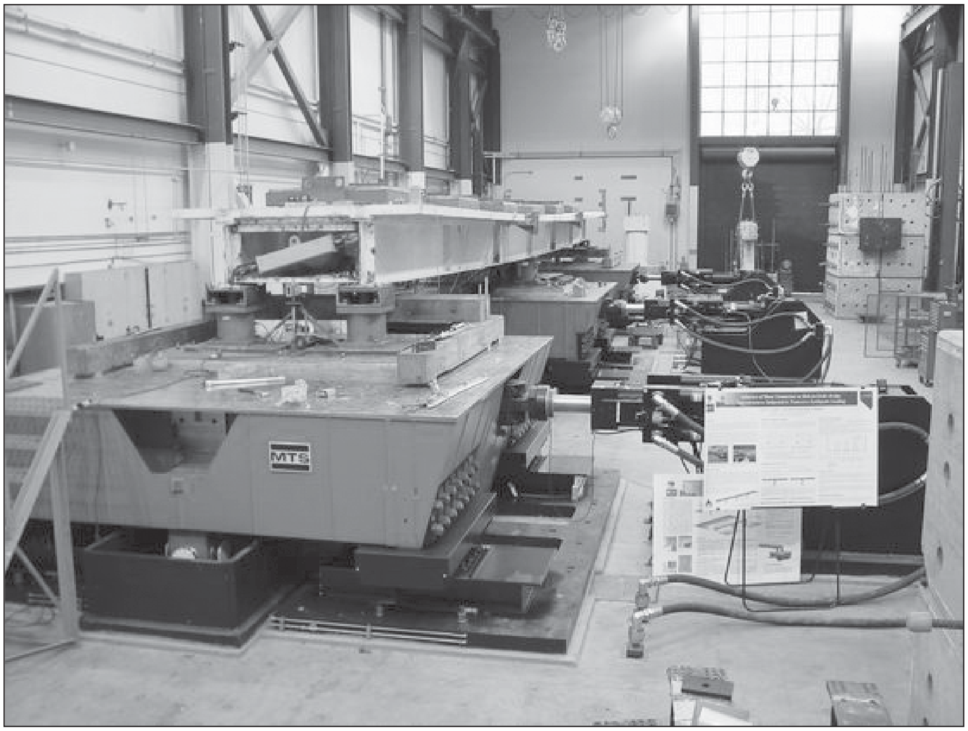


PHOTO COURTESY CCEER, UNIVERSITY OF NEVADA

The three shake tables at the University of Nevada in Reno put to the test a 200-ton model reinforced with nitinol instead of steel.

Nitinol May Provide Flexible Strength to Bridges During Earthquakes

The earthquake in Italy on April 6, 2009, underscored the vulnerability of historic stone structures such as medieval homes and churches. It also underscored the vulnerability of far younger steel and concrete bridges. When the 6.3 magnitude quake hit, it cracked a bridge in half and dumped it into the Aterno River.

Earthquakes put bridges under enormous stress because the ground movement can start at one end of the bridge advancing to the other end, creating highly destructive vibrations. The length of the bridge, its design and materials, the type of soil on which it is built, and the magnitude and characteristics of the earthquake all affect a bridge's ability to withstand damage.

Unfortunately, when a bridge or an overpass collapses, the result is not simply inconvenience for drivers. It can mean that the injured are cut off from medical help; that humanitarian aid must be airlifted until a temporary bridge is constructed; and that the economic disruption of a community's life will be of long duration.

Recent research in Europe and the United States indicates that nitinol, the uniquely bonded combination of titanium and nickel (also known as NiTi), may be one of the ways to build safer bridges. Steel can keep a bridge upright following an earthquake, however, the steel is permanently distorted. Nitinol, with its shape-memory, would enable a bridge to "remember" its former shape and return to it.

Shape-Memory

Nitinol has been the subject of much research into its potential use in a bridge's infrastructure instead of steel. It is known as a shape memory alloy (SMA) although technically it is not an alloy but an intermetallic compound of titanium and nickel in nearly equal proportions. Shape memory means that its crystal structure changes sharply with temperature change. It is thermally reversible.

Because of its shape-memory and super-elasticity, nitinol is used frequently for small items such as cardiovascular stents, titanium eyeglasses and orthodontics, but it also holds out promise for large structures. For example, experiments have been carried out at the Eucentre (European Centre for Training and Research in Earthquake Engineering), Pavia, Italy, on the use of nitinol bracing systems to reduce vibrations. However, for all researchers the difficulty has been that full-scale behavior of bridges under varying seismic conditions is impossible to replicate.

Two-Hundred Ton Model Gets a Hard Shake

The closest any team of scientists and engineers has come took place in December 2008 when a ten-second experiment was conducted using three shake tables at the Center for Civil Engineering Earthquake Research (CCEER) at the University of Nevada in Reno. This is the only facility in the United States that can replicate experimentally large earthquakes. The experiment involved a 110-foot-long concrete girder bridge that was a quarter-scale replica of the one that collapsed in the Northridge, Calif., earthquake in 1994.

The earthquake that took place in Sichuan Province, China, on May 13, 2008, did extensive damage to bridges.

The difference was the 200-ton model was reinforced with nitinol instead of steel.

The CCEER team simulated a magnitude 8 earthquake. The data from the movement sensors showed that the concrete suffered damage but the infrastructure remained intact. The nitinol underwent deformation but then returned to its shape once the shaking stopped. It appeared to reduce the bridge's residual tilt to almost zero.

Earlier research by the CCEER team along with scientists at Rice University and Georgia Institute of Technology found that nitinol restrainer cables had the ability to dissipate energy, exhibited minimal residual strain after repeated loading, and withstood many cycles with little strength and stiffness degradation. Other experiments pointed to nitinol's use in suspension bridges.

The CCEER facility is a $10 million state-of-the-art laboratory in the field of bridge engineering. The Large-Scale Structures Laboratory at the University of Nevada, Reno, is an Equipment Site under the NSF-funded George E. Brown Jr. Network for Earthquake Simulation (NEES). The goal of NEES is to improve understanding of earthquakes and their effects. Ti

The vulnerability of steel and concrete bridges, such as this bridge over the Aterno River, was underscored by the earthquake in Italy on April 6, 2009.

A History of Destruction

In the United States two earthquakes in the past 20 years did extensive damage to bridges and overpasses. These earthquakes led to changes in the way bridges and overpasses are designed and constructed. However, there is significant room for improvement.

The Loma Prieta earthquake, that occurred on the San Andreas Fault, hit the San Francisco Bay area on October 17, 1989, just as the third game of the World Series was about to start. The structural damage was extensive, with double-decker portions of the Cypress Street viaduct on Interstate 880 collapsing, partially due to the fact that the viaduct had been built on unstable marshland that amplified the shaking. A 50-foot section of the San Francisco-Oakland Bay Bridge also collapsed.

The earthquake that hit Northridge, Calif., in 1994 caused an estimated $20 billion in damage. The 6.9 magnitude earthquake was unusual because it produced very strong ground accelerations. The freeway system around Los Angeles was badly damaged. The interchange between Interstate 5 and State Route 14 collapsed. The Santa Monica Freeway also had to be closed. Ti

During the January 17, 1994, Northridge earthquake near Los Angeles, Calif., a section of I-10 collapsed.

A section of the San Francisco-Oakland Bay Bridge collapsed in the Loma Prieta earthquake that occurred on October 17, 1989. So also did the double-decker portions of Interstate 880.

The Hilton Waikoloa Village.

Titanium 2009 ITA Convention in Hawaii

On September 13-16, the International Titanium Association (ITA) will hold its Annual Conference and Exhibition at the Hilton Waikoloa Village, located on the Kohala Coast of the Big Island of Hawaii.

All components of the titanium industry will be represented, which makes the conference an excellent networking opportunity. Attendees will have the chance to learn firsthand about the latest technological and economic developments taking place around the world. Two highly regarded workshops – the Fundamentals of Titanium and the Welding of Titanium – will be offered on Thursday, Sept. 17, following the conference.

The 15th Annual ITA Golf Classic will be held on Saturday Sept. 12 at the Waikoloa Kings' Golf Course. The 7,000+ yard course was designed by former British Open champion Tom Weiskopf and Jay Morrish and offers a great links-style layout that reflects the rugged seacoast of Scotland yet is set in an island paradise dotted with ancient lava flows and palm trees. (For more information, go to www.titanium.org) Ti

Pool at Waikoloa Village.

ATI Rowley, Utah, Plant on Target for Third Quarter

Despite the economy, Allegheny Technologies' new premium-grade sponge facility in Rowley, Utah, and its titanium and superalloy forging facility in Bakers, NC, will be operational in the third quarter of 2009. According to L. Patrick Hassey, Chairman, President and Chief Executive Officer, "These strategic investments enhance our capabilities to serve our core long-term growth markets including aerospace and defense, chemical process industry, oil and gas, electrical energy, and medical."

Melt Shop

The melt shop consolidation at ATI's Brackenridge, Penn., plant is also progressing, with cost savings expected to begin in late 2010. Engineering, permitting and site preparation continues on the Brackenridge hot rolling and processing center.

At the center of the multi-building complex in Rowley is the 230,000 square-foot processing facility. When it reaches full capacity in 2010, it is expected to produce 24 million pounds of sponge per year. Staffing is expected to be about 150 employees. Ti

Air Force Awards Contract to Cristal US, Inc.

Fourth Quarter Plant Completion

The Air Force has awarded a cost share technology investment agreement contract to Cristal US, Inc. for $9,025,000. This contract is for the Defense Production Act Title III Phase I Program to increase and enhance the domestic capability to produce metallic titanium powder and related articles.

The contract is a partnership between International Titanium Powder LLC (ITP) and Title III for construction of a plant in Ottawa, Illinois. The plant will be completed in the fourth quarter of 2009, coming online in 2010.

ITP specializes in the Armstrong Process, a proprietary, patented process for the low-cost production of titanium powders. To help develop the process, ITP received funding as part of DARPA's Titanium Initiative from 2003 to 2006. Cristal US, Inc., a wholly owned subsidiary of Cristal Global, acquired ITP in 2008. Ti

PHOTO COURTESY OF NASA

Meteorites contain titanium-50 and titanium-46. This photo of the Geminid meteors was taken in December 2004 in Roundtimber, Texas by Jason A.C. Brock.

Data on the Formation of Solar System Gained from the Study of Titanium In Meteorites

It is common knowledge that the universe is filled with the debris of exploded stars. By studying meteorites, scientists can determine what materials were in the debris clouds that ultimately led to the formation of our solar system.

Recently a team lead by Martin Bizzarro of the Natural History Museum of Denmark measured levels of titanium in inclusions in meteorites as well as from samples from the moon and Mars. Their rationale for doing so was that titanium has several stable isotopes that can be used to cross-check findings.

The scientists found that the concentration of titanium varied from sample to sample. However, two titanium isotopes – titanium-50 and titanium-46, were always found in the same ratio. Titanium-50 contains 22 protons and 28 neutrons. Titanium-46 contains 22 protons and 24 neutrons. Titanium-50 is commonly created when white dwarf stars explode. Titanium-46 is created inside the cores of massive collapsing stars.

The supposition is that if these two isotopes come from different sources yet are always found in the same ratio, then the dust cloud called the solar nebula must have been homogeneous. More research will need to be done to determine why there are differences between the planets and asteroids. Ti

Dynamet Technology's Innovative Ti Alloys Promise Improved Hydraulic Tubing

Other Military Applications Under Development

Dynamet Technology, Inc., Burlington, Massachusetts, is continuing its SBIR research contract from Naval Air Systems Command (NAVAIR) for development of its innovative damage-resistant titanium alloys for use as hydraulic tubing for the Marine Corp's V-22 *Osprey* and other aircraft tubing applications.

Dynamet's advanced powder-metal-based titanium alloys have the potential for improving the reliability of thin-wall hydraulic tubes that are critical to the functioning of the aircraft's control system.

Army Aircraft Impellers

Advanced turboshaft engine impellers are under development at Dynamet Technology for Army aircraft application under an SBIR study funded by Army RDECOM (Eustis, VA).

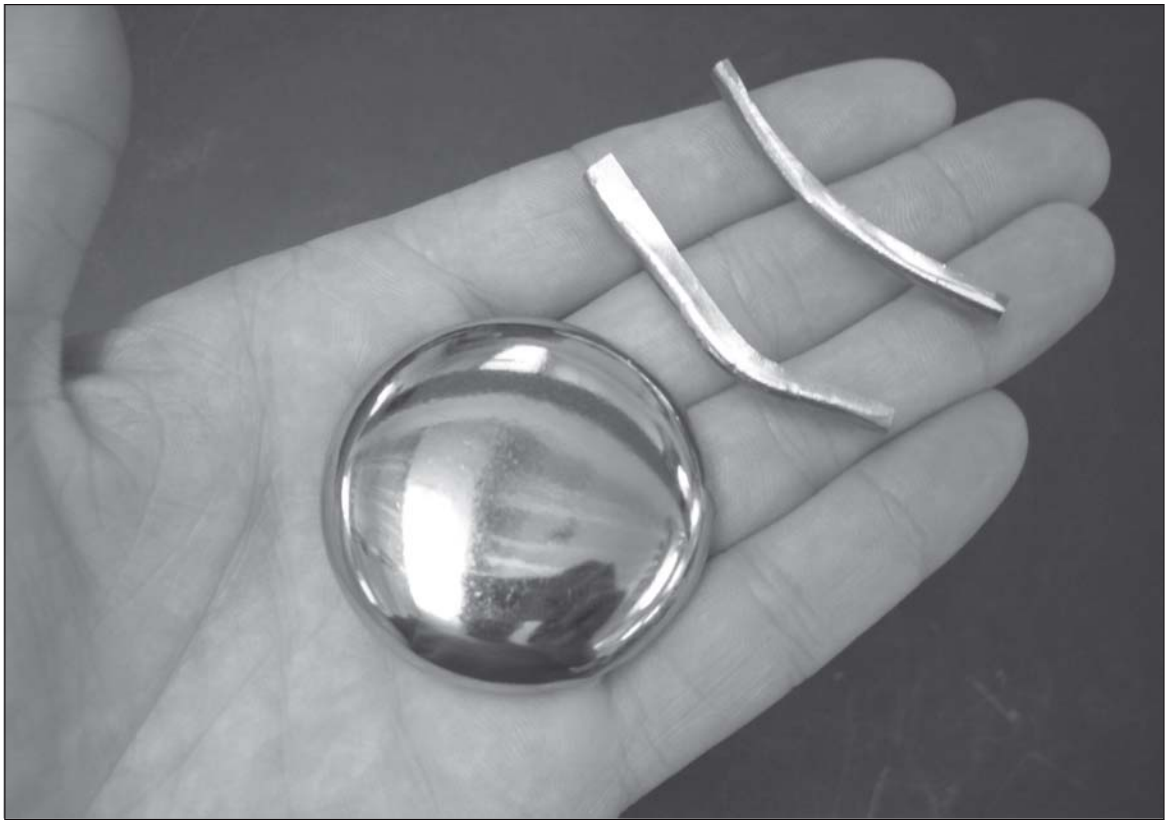
Advanced ceramic particulate reinforced titanium metal matrix composites (MMC's) have demonstrated superior room and elevated temperature strength, higher stiffness and improved creep resistance over conventional titanium alloys.

Reducing Weight of Marine Corp's Expeditionary Fighting Vehicle

Dynamet Technology is also scaling up its promising manufacturing technology for the production of low-cost titanium alloy cast and forged components for the Marine Corp's advanced amphibious landing craft, the Expeditionary Fighting Vehicle (EFV). This R & D will build on the successful results achieved in a Phase I study.

Sponsored by the Navy, the Phase II SBIR is aimed at reducing the weight and improving the reliability of the EFV by the substitution of titanium for steel in critical components.

This low-cost effort utilizes essentially all recycled titanium alloy turnings and has led to the formation of a Dynamet Technology spinoff called NuLife Titanium LLC. Ti



Samples of the new titanium-based metallic-glass composites show their toughness and ductility.

Caltech Scientists Create Titanium-Based Structural Metallic-Glass Composites

New alloys are lighter and less expensive, but are still tough and ductile enough for use in aerospace applications

Scientists from the California Institute of Technology (Caltech) have created a range of structural metallic-glass composites, based on titanium, that are lighter and less expensive than any the group had previously created, while still maintaining their toughness and ductility (the ability to be deformed without breaking).

A paper describing these breakthrough metallic-glass alloys has now been published in the *Proceedings of the National Academy of Sciences* (PNAS).

Early in 2008, the same Caltech group had published a paper in the Journal *Nature* describing new strategies for creating the liquid-metal composites. This research resulted in "alloys with unrivaled strength and toughness," notes Douglas Hofmann, visiting scientist and lead author on the PNAS paper that, along with the *Nature* paper, describes work he did while a graduate student at Caltech. "They are among the toughest engineering materials that currently exist."

Still, there were shortcomings to the alloys presented in *Nature*. Because they were created mainly for use in the aerospace industry, they needed to have very low densities. Ideally, the alloys would have had densities in or around those of crystalline titanium alloys, which fall between 4.5 and 5 grams per cubic centimeter (g/cc). The original alloys, made predominantly of zirconium, fell between 5.6 and 6.4 g/cc, putting them "in a no man's land of densities for aerospace structures," says Hofmann.

And so Hofmann and his colleagues (including William Johnson, Caltech's Ruben F. and Donna Mettier Professor of Engineering and Applied Science, and a pioneer in the creation of metallic glass) began tweaking the components in their composites, eventually coming up with a group of alloys with a high percentage of titanium, but which maintained the properties of the previously created zirconium alloys.

"Despite being based in titanium," Hofmann notes, "these alloys exhibit the same impressive properties as the zirconium alloys. They are still tough – in other words, they resist cracking – and they are still ductile. In fact, they are even more ductile than the alloys we'd created in the past."

This decrease in density also resulted in a reduction in cost, adds Hofmann, since zirconium is a more expensive metal than is titanium.

The work detailed in the paper, "Development of tough, low-density titanium-based bulk metallic glass matrix composites with tensile ductility," was supported by the U.S. Office of Naval Research. Hofmann was supported by the U.S. Department of Defense through the National Defense Science and Engineering Graduate Fellowship program.

The paper's coauthors include Johnson; Caltech graduate students Jin-Yoo Suh and Aaron Wiest; Mary-Laura Lind, a visitor in materials science; and Marios Demetriou, a senior research fellow in materials science. (For more information see http://mr.caltech.edu/media) Ti

PHOTO COURTESY OF GREG VAN RIEL

Titanium Cladding Not an Optical Illusion on Art Museum

This strange yet beautiful photograph was submitted to *Titanium News* following publication of an article in the Winter 2009 issue. Designed by world-renowned architect Frank O. Gehry, the new addition to the Art Gallery of Ontario is clad in blue titanium. From this viewpoint, it seems to hover over an older Toronto neighborhood, while its cantilevered staircase appears to perch in the branches of a tree. The cladding was manufactured by Nippon Steel, supplied by Prime Metals Inc., and installed by Flynn Canada, Ltd. Ti

Total Titanium Replacement Gives Man a New Leg to Stand on

Advances in orthopedic medicine continue to show promise in the uses of titanium to replace damaged bones and joints. Titanium is common in hip replacements, which usually involve the head of the femur only. Much more rare is the replacement of the entire femur, extending from the hip to the knee.

The total replacement procedure is performed on less than 100 patients annually in the U.S., most of them being younger patients suffering from bone cancer. But now an octogenarian has joined the group. In September 2008, Gene Johnson, an 81-year-old salesman and former high school football, volleyball and track coach, was faced with amputation of his right leg due to continuing complications from prior hip-replacement surgeries. Instead of amputation, Dr. Henry Finn, Chief of Orthopedic Surgery at Weiss Memorial Hospital and director of the University of Chicago Bone and Joint Replacement Center at Weiss, recommended that the femur, as well as the hip and knee be replaced.

Removing Femur

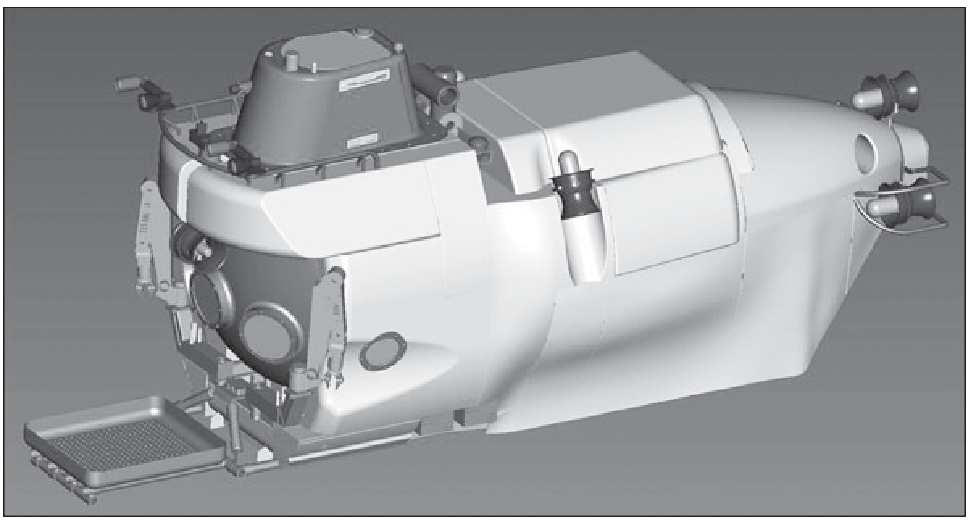
In a press release from Weiss Hospital, Dr. Finn said, “We generally don’t like to take out of the body what God gave us and put in something artificial but there’s a point when the bone and soft tissue won’t heal; so the only reasonable option was to remove the entire femur and replace it with metal,” – the metal being titanium. Orthopedic surgeon Kris Alden, M.D., Ph.D. who teamed with Dr. Finn to perform the operation on October 8, described it as “last-resort surgery.”

The surgery involves limb salvage reconstruction using the Orthopaedic Salvage System (OSS™) from Biomet Orthopedics, headquartered in Warsaw, Indiana. Dr. Finn is the inventor of the system. He is also the designer of the Finn Knee™ System. Biomet and its subsidiaries design, manufacture, and market products used primarily by musculoskeletal medical specialists in both surgical and non-surgical therapy.

The total femur is made of a titanium alloy. Biomet’s hip and knee components also benefit from the use of Regenerex® Porous Titanium Construct which provides an enhanced interconnecting pore structure to increase strength and flexibility due to high levels of biologic fixation.

Mr. Johnson is now back in his home in Princeton, Illinois, working with a physical therapist. His goal is to be able to cheer on his hometown teams as well as spend time with his family, including his four great grandchildren. Ti

Element 22 *by Anthony Lopes*



A preliminary view of the HOV.

Ti Sphere *(continued from page 5)*

After the hemispheres are joined, the next steps will be cutting holes and EB welding in the inserts for the hatch, the five viewports (three seven-inch and two five-inch) that are intended for pilots and scientists to view the ocean depths, and two large penetrator plates. When the completed sphere weldment leaves STADCO, it will undergo a post-welding stress relief heat treatment before arriving at SwRI for the final assembly and testing.

Still Unclear: Funding and a Name

In 2004, the National Science Foundation (NSF) awarded WHOI $21.6 million for the *Alvin's* replacement. However, the estimates came in so high, particularly for the titanium, that WHOI decided on a two-phase plan, stretching out the work over a number of years. The first phase began in 2008 and will finish in 2011. Full funding has not yet been obtained for Phase 2.

Yet one more issue still undecided is what will be the name of the new vehicle. Generally a new hull means a new ship and a new name. But by that token, the *Alvin* went out of existence when its steel hull was replaced by titanium back in 1973. *Alvin* is a memorable name, so perhaps its retention with the affixing of the Roman numeral II would be appropriate. Whatever name is chosen, there is no doubt that her lineage reaches back to Vulcan, for she was born out of the fire and shaped by immense forges in preparation to enter the farthest reach of Neptune's kingdom. Ti

The new HOV must be compatible with the existing launch systems and storage hanger size on the Alvin's *research vessel* Atlantis.

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