FIORENTINO Technical Report FPA-152

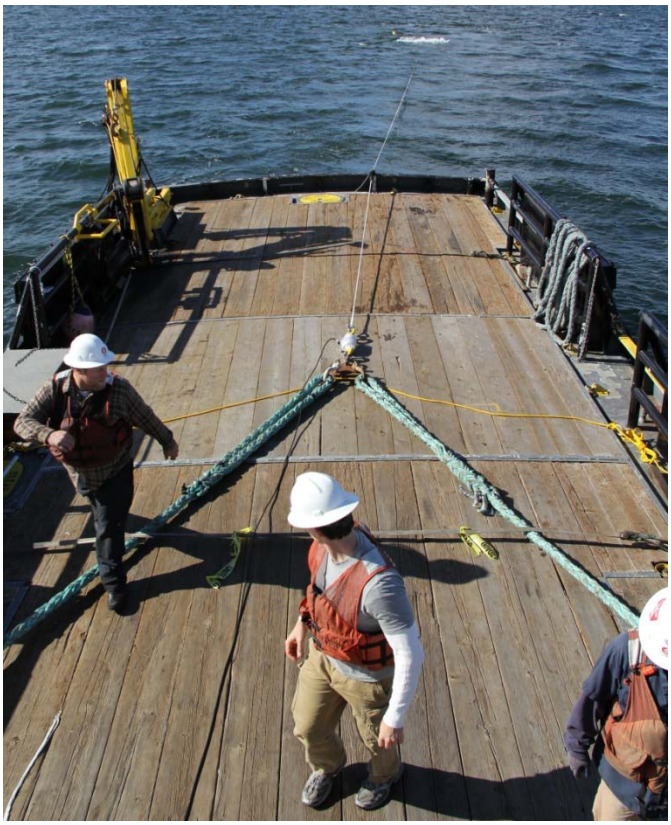
Report Prepared for:
America's next generation of spacecraft

A spacecraft can be a diameter of 16.5-foot and weigh 18,000 lbs. at splashdown. When the parachute sea anchor is attached to the spacecraft in seas up to Sea State 3, it will mitigate the forward motion of the capsule to allow swimmers to extract astronauts.
Photo courtesy of NASA

RESULTS FROM PARACHUTE SEA ANCHOR DRAG TESTS FOR A SPACE CAPSULE,
Jan. 10, 2013

This report presents data on the tensile load strengths and drag characteristics of one six-foot Fiorentino parachute sea anchor with para-ring technology, including the accessory components of rode, bow shackle, and a snap shackle that were all towed behind a crew tugboat. The Fiorentino parachute sea anchor proved to perform above the 150% load test as required for spacecraft capsule recovery. The 150% load test was stipulated as 330 pounds force.

by Zack Smith



Crew move away from the load cell and taut rode leading to the para-anchor since equipment that breaks under load can fly across the deck of the boat causing severe injury.

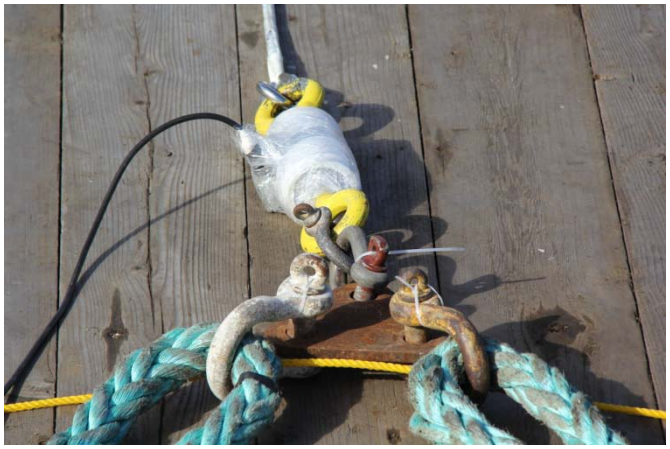
Parachute Sea Anchor Drag Test

Towing parachute anchors and drogues behind a tugboat is one method of measuring drag and the amount of force placed on equipment. By January 2013, Fiorentino had completed a dozen of these tests and find them useful to determine the strength of individual parts that make up a drag device. Additionally, specific knowledge on the products behavior (how much a product spins or yaws) or if a specific part fails to perform is beneficial. Fiorentino has used the same tugboat for its previous twelve tugboat drag tests, including this 13th tow test for America's next generation of space capsules. It's important to note the tugboat has been slightly modified from its original condition so vessel specifications have changed slightly.

SPEC. SHEET—TRIPLE SCREW CREW BOAT

Length (loa):	98'
Length (wl):	93.8'
Disp. tons:	67
Gross tons:	99
Beam:	21'
Draft:	8' 6"
Fuel Cap:	2,600 gal.
F.W. Cap:	600 gal
Max speed:	22 knots
Cruising speed:	18 knots
Engines:	3 3406 Caterpillar
Engine HP:	600 per screw
Propellers (3):	32" D x 32" P 4 blade

Equipment used to measure force



Tension Load Cell: A device that measures the amount of force placed on the object to which it is attached. For the purpose of this report, a remote tension link, ending with an eye-and-eye attachment, was used for the drag tests. The load cell was set at 20,000 lbs. (9,072 kg) x 2 lbs. (1kg) graduations.

Tension Load Indicator: A battery-operated digital indicator required to register load numbers on a small monitor.

A black electric cable connects the load cell to the load cell indicator so the crew can measure force from the safety of a lower deck cabin.

Rigging Setup

The load cell is attached to an amidships rope bridle anchored to sturdy port and starboard posts. The thick bridle lines have virtually no stretch.

A 94.6-foot (28.8 m) x 5/8-inch (16 mm) double braid Dacron/nylon line with splice and thimble on both ends of the line is attached to the eye of the load cell that faces the transom. The double braid line does stretch. Measurement from the load cell eye to the stern of the boat is 25-feet (7.62 m).

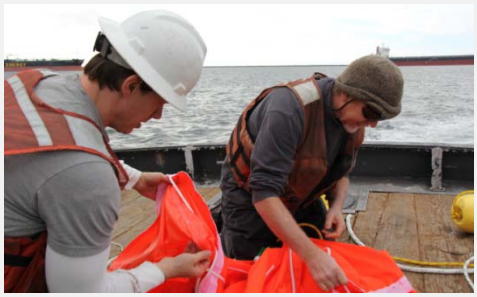
The double braid line is attached to a 3/8-inch (10 mm) glow in the dark rode that measures 65-feet (19.8 m) in length. A ½-inch (13 mm) shackle is used to connect the two lines.

A stainless snap is used to attach the glow in the dark rode to the Para-Ring hardware of the parachute sea anchor. Rope was flaked back and forth before the parachute anchor was deployed over the transom and into the water.

DRAG SPEED CHARACTERISTICS

Force Measurement:
Tugboat idles at an average of 5.1 and 5.2 knots without the parachute sea anchor deployed

Reading/record Number	Time	Engine Rpms Center engine (#2)	Tug Speed with deployed parachute in knots	Lbs. of force registered on the load cell indicator	Notes
One	10:32 am	0	1.7	84 to 100	Captain throttles engine in and out of idle.
Two	10:35 am	0	1.7	200 low 592 high 220 to 250 average	Captain throttles engine in and out of idle.
Three	10:37 am	0	2.6	800 low 1100 high 800 to 932 average	Captain throttles engine in and out of idle.
Test is stopped to reset the load cell.					
Four	10:48 am	0	2.6 to 2.8	680 low 1046 high 972 to 980 average	Captain throttles engine in and out of idle.
Five	10:51 am to 10:57 am	699	2.8	832 low 1190 high 950 to 1000 average	Center engine #2 is now in gear. Parachute rises and sinks into the ocean. Force increases just as the parachute rises to the surface.



Test is complete after 6 minutes. The parachute sea anchor, glow-in-the-dark rode, and corresponding stainless hardware are inspected by spacecraft engineers and Zack Smith (Fiorentino). There was no damage or signs of wear throughout the entire system.

DRAG SPEED CHARACTERISTICS

Force Measurement—shock load test:
Tugboat speeds up to 8.1 to 8.2 knots before the parachute sea anchor is deployed

Reading/record Number	Time	Engine Rpms Center engine (#2)	Tug Speed with deployed parachute in knots	Lbs. of force registered on the load cell indicator	Notes
Six	11:16 am	1162	*8.1	1560	Boat speed was 8.1 to 8.2 knots before the parachute sea anchor was deployed. The parachute sea anchor broke free from the boat suggesting that the 3/8-inch (10 mm) glow in the dark rope broke. *Hard to say how much the parachute sea anchor actually slowed the tugboat. No truly accurate figure available at this point.

Test is stopped and the parachute sea anchor and rode are recovered. After close inspection it was confirmed the rode had accidentally twisted around itself creating a knot. The break in the 3/8-inch (10 mm) glow-in-the-dark rode was at the knot. The parachute sea anchor had no signs of wear or damage.

DRAG SPEED CHARACTERISTICS

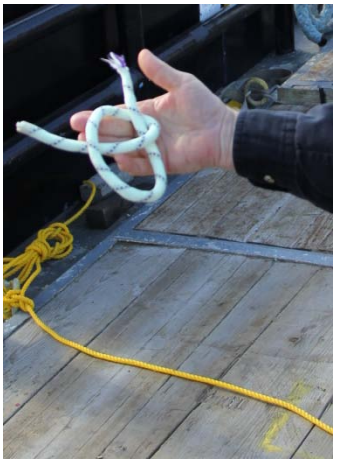
Force Measurement:
Tugboat throttled forward using the center #2 engine.

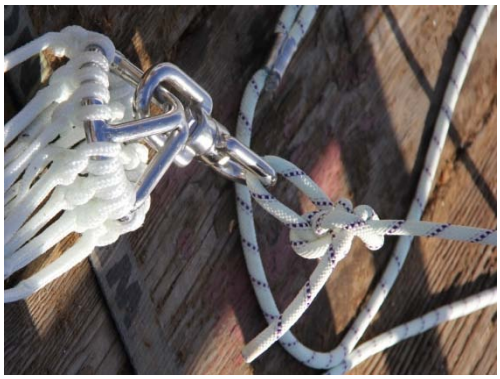
Reading/record Number	Time	Engine Rpms Center engine (#2)	Tug Speed with deployed parachute in knots	Lbs. of force registered on the load cell indicator	Notes
Seven	11:42 am	698	2.8	900 low 1800 high 1200 average	Engine in gear.
Eight	11:44 am	697	2.6	980 low 1144 high 1100 average	Engine in gear.
Nine	11:46 am	807	3.1	1100 low 1228 high 1100 average	Engine in gear.
Ten	11:47 am	No reading	No reading	1146 low 1160 high 1146 average	Boat had to be turned to avoid an anchored crude carrier causing the tugboat to partially slow.
Eleven	10:48 am	842	3.2	1360 low 1552 high 1404 to 1450 average	Engine in gear.
Twelve	11:49 am	972	3.7 to 3.8	1149 low 1886 high 1750 to 1850 average	Engine in gear.
Thirteen	11:50 am	972	3.9 to 4.0	1756 low 2072 high *1756 average	*1756 was a consistent reading on the load cell indicator.

DRAG SPEED CHARACTERISTICS

Force Measurement:
Tugboat throttled forward using the center #2 engine.

Reading/record Number	Time	Engine Rpms Center engine (#2)	Tug Speed with deployed parachute in knots	Lbs. of force registered on the load cell indicator	Notes
Fourteen	11:51 am	1077	4.3	2218 low 2274 high *2274 average	*2274 was a consistent reading on the load cell indicator.
Fifteen	11:52 am	1126	4.4	2608 low 2780 high 2678 average	Engine in gear.
Sixteen	11:53 am	1127	4.5	3014 low 3200 high 3014 average	The parachute sea anchor broke away from the boat indicating that the glow in the dark rode broke for the second time during these series of tow tests.
Test is stopped and the parachute sea anchor and rode are recovered. After close inspection it was confirmed the rode had broken at the bowline knot. The knot was used to attach the rode to the eye and eye swivel located on the Para-Ring hardware of the parachute. Spacecraft engineers and Zack Smith (Fiorentino) inspected the parachute sea anchor and found no signs of wear or damage.					





The 3/8-inch (10 mm) glow in the dark rode has a rated break strength of 5820 lbs. It broke at 3200 lbs. of force at the bowline knot that was tied off to a swivel. As a reminder, 7/16-inch glow in the dark rode is to be used for the Space Capsule Recovery System. Its rated break strength is 6877 lbs. The final 65-foot rode built for the recovery system will not be designed with knots in the system, but with a single eye loop (for the moment) on one end for attachment to the module and a stainless eye on the opposite end so the rode can be shackled to the parachute sea anchor. However, we now have some idea about rode strength if a knot accidentally incurs in the rode during the recovery process.

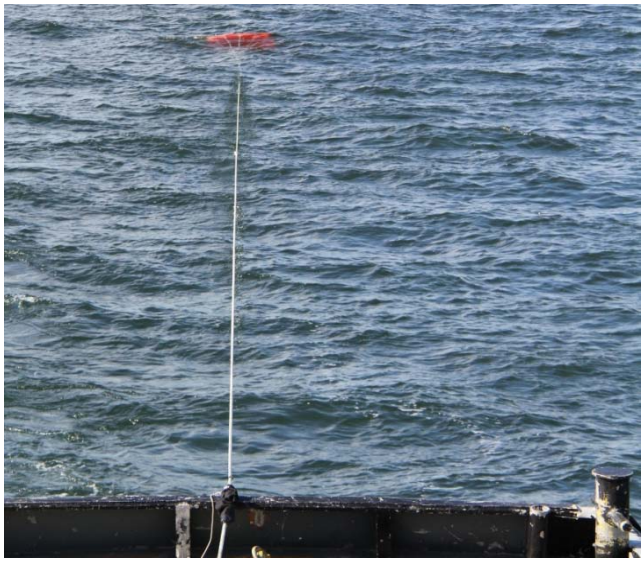
Drogue Jumping

Defined by Fiorentino as a parachute sea anchor or storm drogue that is pulled until partially exposed above the ocean's surface or one that becomes airborne. The following drogue jumping traits may occur with these devices: 1. A speed-limiting drogue that becomes airborne may bounce forward toward a vessel. 2. Stopping drogues typically have several cone elements pull out of the ocean's surface when it "jumps" from the water. In such instances, the stopping drogue loses much of its holding power. Drogue jumping may also occur with drift or parachute sea anchors, but Fiorentino's team has only witnessed this trait during tugboat tow tests. Fiorentino utilizes tugboats to measure drag characteristics and component strength of parachute anchors. The large amount of force generated by a tugboat can cause a para-anchor to partially "jump" out of the water.

The sharp vertical pull created by the height of the tugboat and the deployment of a short length of rode appear to be contributing factors to this "jumping" phenomenon during tugboat tow tests. Another contributing factor is the design of the parachute canopy. Most parachute sea anchor canopies are designed in a circular pattern and are made from a solid fabric to trap more water in an effort to nearly stop the drift of the vessel. This is what makes the para-anchor so effective at bringing drift rates down to 0.5 to 1.0 knots of drift in a single hour.

Slots could be placed in the canopy to reduce drogue jumping, but then the device would lose its holding ability and perform more like a storm drogue. Storm drogues have slots built into them so the device only slows a vessel enough to improve its steering capability. The storm drogue is able to achieve this by holding the stern of a boat down so the boat's rudder remains submerged and the drogue helps keep the boat from falling down a large storm wave.

It's important to note that drogue jumping almost never occurs in real-life sea trials and is less likely to occur in the planned recovery of the space module in sea states 1 through 3.



The highest amounts of force recorded on the load cell indicator occurred as the fully inflated para-anchor rose to the surface; just before it popped out of the water. Force is reduced as the para-anchor dives and starts to re-inflate itself at the same time the anchor rode starts its process of tightening up.

Any force placed on the rode leading to the parachute sea anchor causes it to rise to the surface. Excessive force pulls the parachute to the surface very quickly causing what Fiorentino refers to as "drogue jumping." This is where a parachute sea anchor becomes partially exposed above the ocean's surface looking as though it wants to jump out of the water.