SnT2017/T3.5-P52 Navy's Shock Trials on Warships As Opportunities for IMS And USGS Seismic System Evaluation And Calibration

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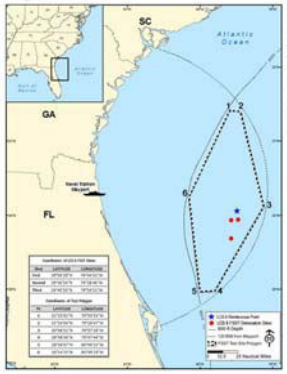
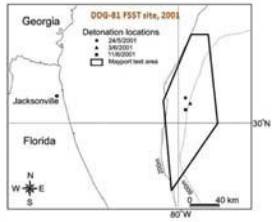
The U.S. Navy conducts *"full ship shock trials"* (FSST) on newly-constructed ships to evaluate and validate the ship's ability to withstand the effects of nearby underwater explosion and retain required capability. The shock trial attempts to simulate the effects of a near-miss underwater explosion by detonating 10,000 pound high explosive charges near the ship. On June 10, June 23, and July 16, 2016, respectively, the Navy carried out three FSSTs on the Littoral Combat Ship *USS Jackson* (LCS-6) off the Florida coast. The three events were well recorded in the eastern United States, and the U.S. Geological Survey (USGS) reported the events as "experimental explosions", with magnitudes in 3.7-3.8; and 78, 82, and 114 associated/picked phases, respectively. The CTBTO's seismic bulletin has the first and third FSSTs reported, but not the second. CTBTO's International Monitoring Systems (IMS) stations in the United States (Tuckaleechee, TN; Lajitas, TX; Mina, NV; Eilson, AK), Canada (Lac du Bonnet), Turkey (Belbashi), Finland (Lahti), and Australia (Warramunga, Alice Springs) saw some of these events. In addition, five hydrophone channels at CTBTO/IMS Ascension Island hydroacoustic array detected two events. CTBTO/IDC did not "screen out" the detected FSSTs as earthquakes. Both USGS and IDC seismic locations are fairly reasonable. In the case of USGS, the events are off shore, while most of the reporting seismic stations are on land, on one side. The test area selected by the Navy for FSSTs is a narrow hexagon, bounded by two arcs: the 600-ft depth bathymetry on the west, and an arc of radius 120 nautical miles centered at Mayport Naval Station (Florida). The seismic solutions determined by USGS and IDC lie inside the hexagon, using the standard single-event location algorithm. In the seismic monitoring mission area, it has been well known that the best calibration data points are those well-recorded, controlled active-source experiments for which the Ground Truth (of the event size, origin time, and coordinates) are known – such as the 100-ton *"Omega"* explosions carried out by the United States and Kazakhstan in 1997-2001 for the purpose of destroying the unused Soviet shafts and adits at Semipalatinsk. Navy's FSSTs have similar potential for evaluation and calibration of the seismic (and/or hydroacoustic) systems operated by the USGS and CTBTO.

LCS FSSTs Off GA-FL Coast



Navy conducts the LCS FSSTs off Florida coast, in water with 600 ft depth, and within 120 nautical miles from Mayport Naval Station. A hexagon is posted by National Marine Fisheries Service. The site was also used for FSSTs of DDG-81 *(USS Winston S. Churchill)* in 2001.



CTBTO/IMS Stations That Saw FSSTs

- IMS Stations in CONUS, Canada, Finland, Turkey, and Australia saw FSST1 of 06/10/2016
- PKP phase visible at WRA and ASAR (in Australia)
- In US: Tuckaleechee Caverns (TN) and Lajitas (TX) saw FSST1
- In US: Lajitas (TX), Eilson (AK) and Mina (NV) saw FSST3 of 07/16/2016
- HA10 (Ascension Island) saw FSST1 and FSST3

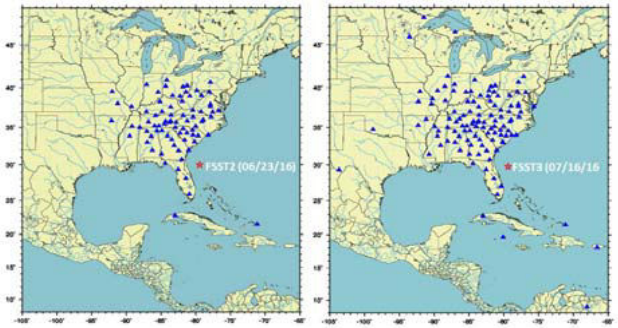
CTBTO/IMS Stations Used in Forming Events Corresponding to 2016 FSSTs on LCS-6

FSST2 not in IDC official SHI bulletin means *"the event was not formed within the permitted data-processing time window"*. Some individual IMS stations do have recorded signal with adequate S/N ratio and can be "associated" for off-line studies.

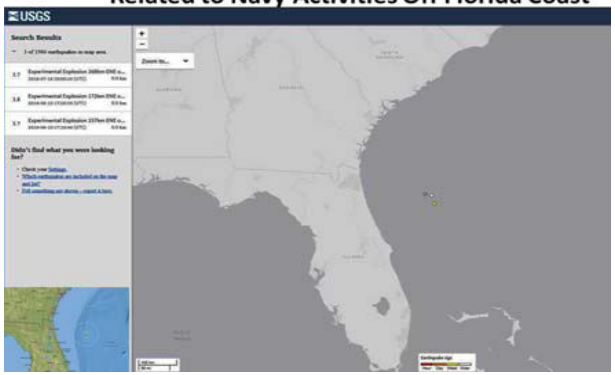
Station	Country	Code	Place	Type	FSST1	FSST2	FSST3
AS107	USA	TKL	Tuckaleechee Caverns, TN	3-C	V	ϕ	-
PS46	USA	LJTX (TXAR)	Lajitas, TX	array	V	ϕ	V
PS47	USA	MNV (NVAR)	Mina, NV	array	-	-	V
PS49	USA	ELAK	Eilson, AK	array	-	-	V
PS8	Canada	ULMC (ULM)	Lac du Bonnet, Man.	3-C	V	-	-
PS43	Turkey	BRTR	Belbashi	array	V	-	-
PS17	Finland	FINES	Lahti	array	V	ϕ	-
PS2	Australia	WRA	Warramunga, NT	array	V	ϕ	V
PS3	Australia	ASAR	Alice Springs, NT	array	V	-	V
H10	UK	H10 (HA10)	Ascension Island	hydro	V	ϕ	V

All 3 LCS FSSTs Were Very Well Recorded In Eastern United States

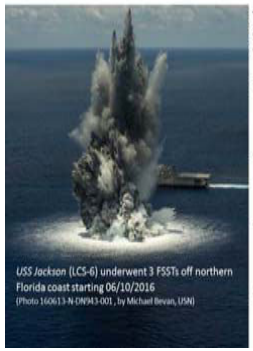
(78, 82, & 114 phases picked by USGS, respectively.)



USGS/NEIC Bulletin Has Three Recent Events Related to Navy Activities Off Florida Coast



"Full Ship Shock Trials" on Key Warship Classes



The U.S. Navy has tested several classes of commissioned warships:

- *USS John Paul Jones* (DDG-53) of Flight I DDG-51 (*USS Arleigh Burke*) class,
- *USS Winston S. Churchill* (DDG-81) of Flight IIA DDG-51 class,
- *USS Mesa Verde* (LPD-19) of *USS San Antonio* (LPD-17) class,
- *USS Jackson* (LCS-6) of *USS Independence* (LCS-2) class.

Why *"Full Ship Shock Trials"* on The 3rd Ship?

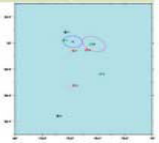
Per Navy and Congressional Research Service: *Testing on the 3rd or later ship is preferred or necessary: (1) it would be more representative of the ships of the class, (2) it allows lessons from the first two ships be incorporated, (3) shock tests on individual systems and components must be conducted prior to a FSST, and (4) preparation and environment assessment for FSST inevitably take time.*

Reported Parameters of FSSTs on LCS-6

Source	Date	Time	Lat°N	Lon°W	Reported Δ	M_b, M_L
USN 1	6/10/2016	13:12 EST	29.941	79.575	---	---
USN 2	6/23/2016	13:20 EST	29.948	79.479	---	---
USN 3	7/16/2016	16:01 EST	29.676	79.573	---	---
USGS 1	6/10/2016	17:10:48 UTC	30.022	79.645	±6.3km	3.7±0.3
USGS 2	6/23/2016	17:20:20 UTC	29.991	79.448	±4.8km	3.8±0.1
USGS 3	7/16/2016	20:00:10 UTC	29.765	79.377	±6.3km	3.7±0.2
CTBTO 1	6/10/2016	17:10:49 UTC	30.084	79.633	36kmx17km	3.6
CTBTO 3	7/16/2016	20:00:12 UTC	29.442	79.687	68kmx6km	3.2

* 10,000 pounds of plastic bonded explosive (PBX) charge used in each FSST, equivalent to 7 tons of TNT (per Lyn Carroll, USN, 2001)

** Courtesy of: (1) U.S. Navy / ASD(RDA) / LCS PAPM Test & Evaluation (PMS 501S), (2) U.S. Geological Survey / National Earthquake Information Center, (3) CTBTO / PTS / International Data Center



Comments on Navy's FSSTs and Seismic Reporting from CTBTO & USGS

- FSSTs on LCS-6 in June-July 2016 offer a good opportunity to assess the preparedness & performance of CTBTO/(IMS,IDC) and USGS/NEIC in a region of known low seismicity
  - FSSTs were observed at regional and even some teleseismic seismic stations
  - IDC did not "screen out" FSST1 and FSST3 events
  - FSST2 not in IDC's official SHI bulletin due to [1] constraints on permissible window for bulletin posting & [2] requirement of number of detections
- FSSTs of a ship are of the same explosive size and confined in generally the same geographic area, thus they constitute a good training data set to calibrate seismic (and hydroacoustic) source and propagation models
  - Navy has three similar FSSTs planned for LCS-5 (*USS Milwaukee*, the 3rd unit of *USS Freedom*-class LCS)
  - FSSTs have a potential as GT0 events for the seismic community