BURIED OBJECT SCANNING SONAR (BOSS)

The BOSS-SAS (Buried Object Scanning Sonar-Synthetic Aperture Sonar) system is a bottom looking sonar used for the detection and imaging of bottom and buried targets. The system can generate 3-dimensional image maps. The BOSS-SAS system consists of two wings each having 20 hydrophones and an omni-directional transmitter. The element dimensions are .058 meters by 0.58 meters and equally spaced to provide a real aperture of one meter for each wing. The transmitter operating parameters are listed below:

source level: 190 dB rel to 1 uPa
frequency: 3-20 kHz FM pulse
pulse width: 2 or 5 msec
ping rates: variable (but typically 10 pings per second or 20 pings per second)
sampling rate of system: 44 kHz

Typical vehicle parameters when operating at sea are speeds of 2-3 knots at altitudes between 3 to 5 meters from the bottom. A Bluefin 12.75-inch Unmanned Underwater Vehicle (UUV) with the BOSS-SAS system is shown in Figure 1 and the BOSS-SAS data processing approach is shown in Figure 2.

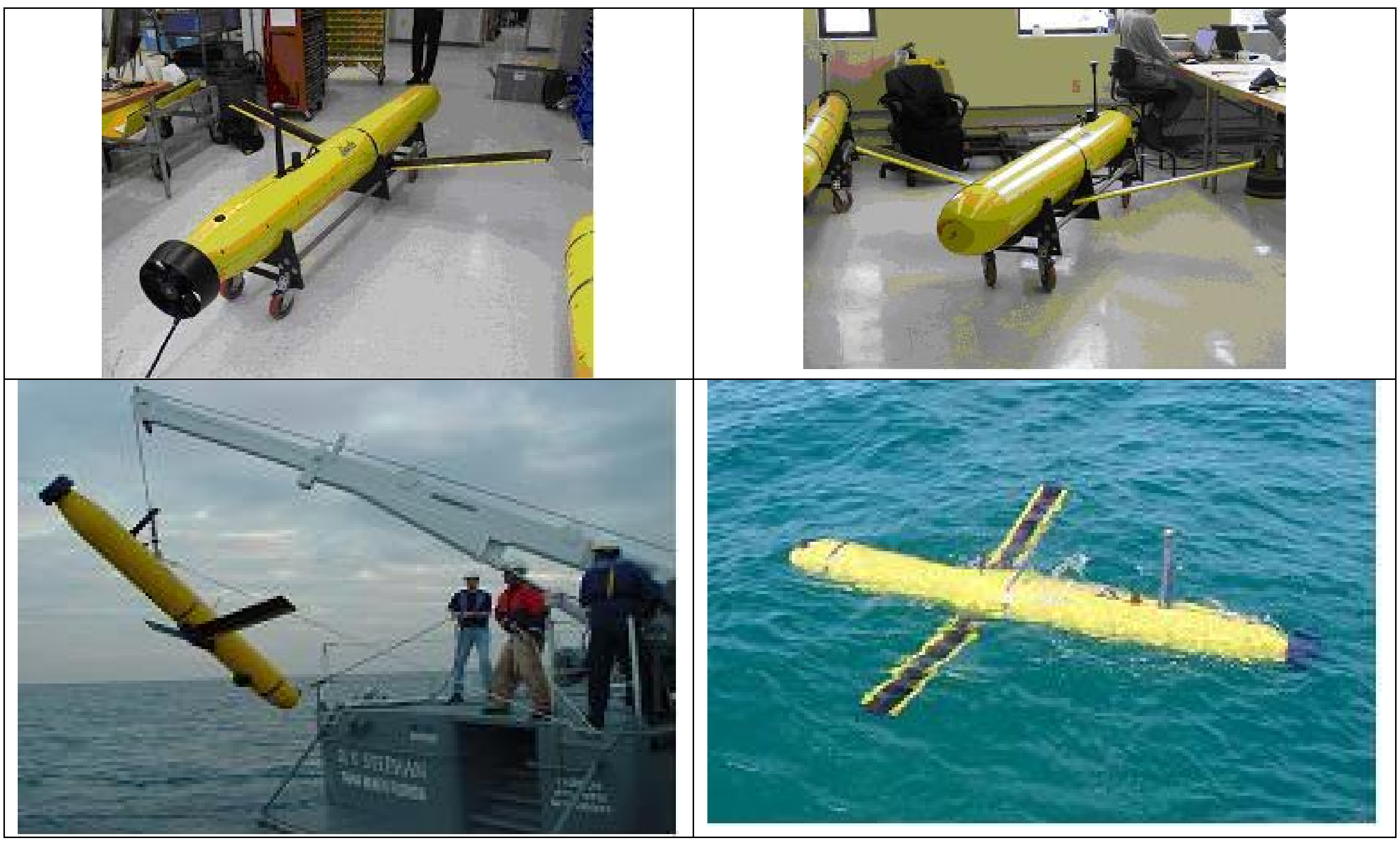


Figure 1. Bluefin 12-inch UUV with BOSS-SAS system.

There are several target fields located throughout the NSWC, Panama City operational areas. During August 2005, field tests were conducted at the 10-meter deep sand target field in the St. Andrew's Bay OPAREA. This area is depicted by the larger square shown in Figure 2.

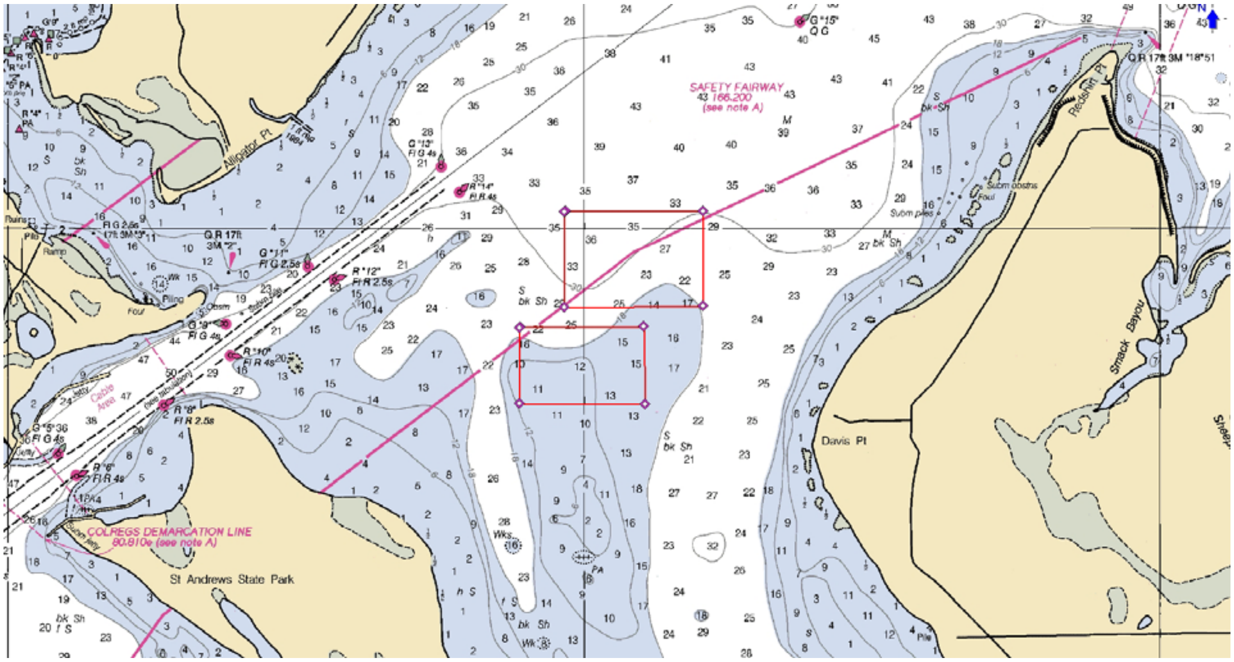


Figure 2. Navigational chart showing the 3 and 10-meter deep sand target fields in the St. Andrew's Bay operational area.

The 10-meter deep sand target field was populated with eleven targets that were buried at the time of deployment. Figure 3, shows some of the targets that were deployed in this field.

Figure 3. Targets deployed in 10-meter sand field.

The initial layout of the field is depicted in Figure 4. The left most target/marker corresponds to the southwest corner of the field. The black circles show the surveyed locations of the targets after several months from deployment.

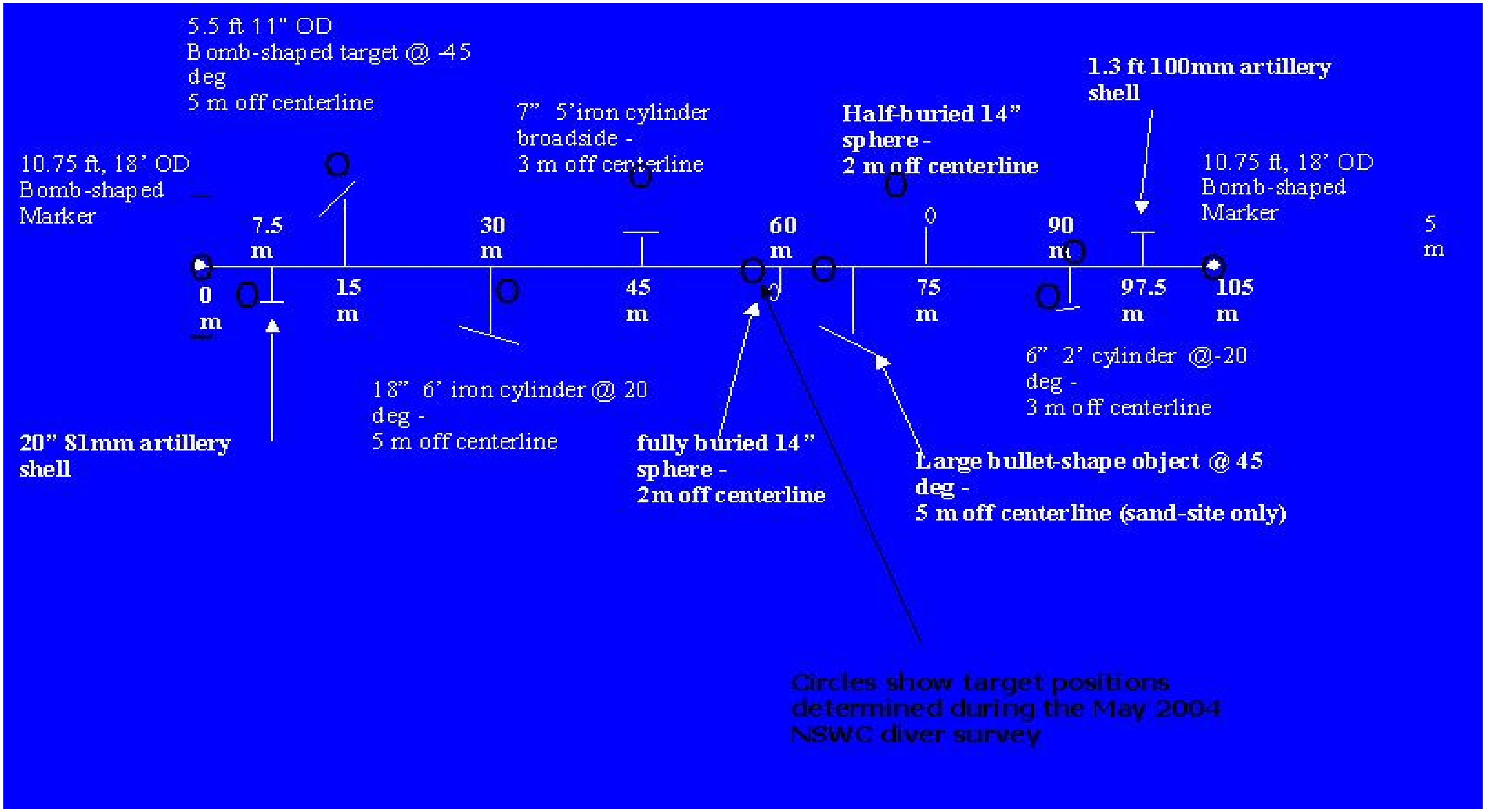


Figure 4. Target layout.

A diver survey prior to the August 2005 field tests was also conducted. Table 1.0 provides the target offsets referenced to the southwest marker. The small target was not found during this survey.

Table 1. 10-meter deep field target survey report.

	Referenced To SW Marker					
	Along Track Range		Off Centerline Range			
	Feet	Meters	Feet	Meters		
SW Marker	0	0	0	0		
Scale bomb-like object	***not found***					
Small bomb	46.95	14.31	24.08	7.34	west	partially buried
18" 6' cylinder	106.57	32.48	5.67	1.73	east	partially buried
7" 5' cylinder	153.28	46.72	21.09	6.43	west	fully buried 6" deep
14" sphere	192.34	58.62	0.91	0.28	east	5" diameter exposed
large bullet-shaped object	217.26	66.22	0.58	0.18	east	?
14" sphere	242.32	73.86	19.25	5.87	west	10" diameter exposed
6" 2' cylinder	295.64	90.11	6.75	2.06	east	?
scale bullet-shaped object	304.87	92.92	3.42	1.04	west	fully buried
NE Marker	353.5	107.75	0	0		

The August 2005 field tests consisted of several calibration runs and several runs prosecuting the target field. An UUV run at a 5-meter height above the bottom with speeds of 2-3 knots was programmed and executed. The UUV tracks and the target locations from the last survey are shown in Figure 5. This figure also shows the tracks referenced to the BOSS data. Six sets of data were recorded. The BOSS data filename format is [surveyfield1{Ar-Fr}NNN.jsf], where {Ar-Fr} corresponds to the data set for the different legs of the run and NNN is incrementing file number. The BOSS data is message based, binary and data is stored in little endian format. The data set associated with {Dr}, a run from the northeast to the southwest, are not available because of an error during the transfer process.

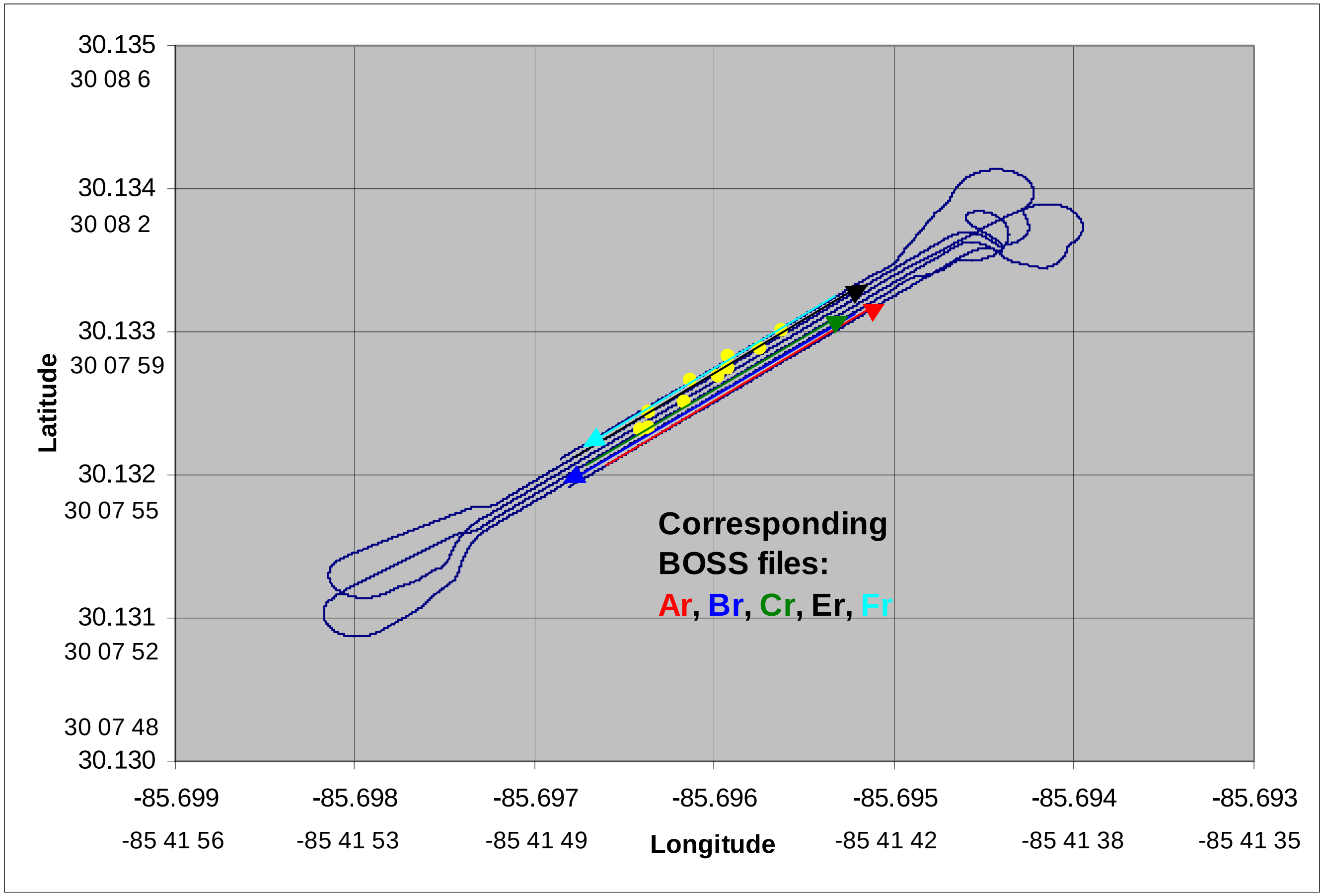


Figure 5. Programmed runs and corresponding data sets.

BOSS DATA

A BOSS data file consists of multiple messages. Each message has a 16-byte header that identifies the message and the number of bytes that follow the header in that message. The following tables provide the header, sub-header and message formats. A short Matlab program has been written to extract the message information from the BOSS data files. However, this program does not map the raw data messages to their respective hydrophones in the BOSS wing receivers.

16-Byte Header

MATLAB Variable	Byte offset	Purpose/Value	Format
	0-3	Reserved	Long
msg_code	4-5	Message code	Short
	6-11	Reserved	3 shorts
n_bytes	12-15	Number of bytes in message	long

Message Code 4007: Pulse Information Messages

The Pulse Information Message consists of a message header and the raw transmit waveform and received match filter.

MATLAB Variable	Byte offset	Purpose/Value	Format
p_name	16-95	Pulse filename	Char
rec_samprate	96-99	Receive ADC sample rate in Hz	Float32
txm_samprate	100-103	Transmit DAC sample rate in Hz	Float32
num_mfcoeff	104-107	Number of match filter coefficients	Long
pulse_gain	108-111	Pulse gain	Float32
mfcoeff_1	112-115	Zero based first coeff in MF	Long
forfft_size	116-119	Forward FFT size of MF	Long
invfft_size	120-123	Inverse FFT size recommended	Long
inv_samples	124-127	Number of good samples in inverse	Long
num_txmsamp	128-131	Transmit samples	Long
txmdelay_samp	132-135	Transmit delay in samples	Long
maxping_rate	136-139	Max Ping Rate	Float32
	140	Number of pulses	
	141	Number of MF	
	142	Number of VGA gain ramps	
	143	Number of pulse phases	
	140-267	Reserved for future use	
txm_data	268+transmit samples	Pulse Data	Signed Short
mfcoeff	Rest of msg	MF FFT coeff (real/imag pairs)	Float32

Message Code 4021: BOSS 40 Channel Raw Data Message

This message consists of a per ping header followed by 40 ADC data frames. An ADC data frame contains the ADC data for all channels for a given sample time.

MATLAB Variable	Byte offset	Purpose/Value	Format
	16-17	Diagnostics ADC 0	Short
	18-19	Diagnostics ADC 1	Short
	20-21	Diagnostics ADC 2	Short
	22-23	Diagnostics ADC 3	Short
	24-25	Diagnostics ADC 4	Short
	26-27	Diagnostics ADC 5	Short
	28-29	Diagnostics ADC 6	Short
	30-31	Diagnostics ADC 7	Short
	32-47	Reserved	
time_4021	48-51	Time in units of seconds since 1970.	Long
tmil_4021	52-55	Milliseconds within the current second	Long
ping_num	56-59	Ping Number	Long
rec_samp_4021	60-63	Sample rate in Hz	Float32
	64-67	Discard samples	Long
	68-69	Event mark number	Long
	70-71	Format of data: 0-BOSS 252 channel, 1-BOSS 40-channel, 2-BOSS 160-channel.	Short
	72-111	Reserved.	
	112-end	ADC Data Frames (Raw Data)	
ADC Data Frame Format 1: BOSS 40-channel			
	112-117	Reserved.	
	118-119	Options bit. If bit 6 is set then this is a special diagnostic data frame that should be ignored. The third sample in every ping should be a diagnostic frame.	Short
	120-127	Reserved.	
data	128-207	ADC Channel Data. There are 40 short integer values in this array, one for each ADC converter/hydrophone in the system.	Short

Message Code 4023: Blue Fin AUV Message

This message consists of a single NMEA string from the AUV. The formats are defined in the Blue Fin interface document. The string consists of a time stamp (acquisition time) and the NMEA string.

MATLAB Variable	Byte offset	Purpose/Value	Format
nmea_time	16-19	Time in units of seconds since 1970.	Long
nmea_tmil	20-23	Milliseconds within the current second	Long
	24-27	Reserved	Long
	28-end	NMEA string	Char

Message Code 4013: Estimated Pitch, Roll Yaw, Heading Message

This message consists of a single reading set of pitch/roll/yaw.

MATLAB Variable	Byte offset	Purpose/Value	Format
prd_time	16-19	Time in units of seconds since 1970.	Long
prd_tmil	20-23	Milliseconds within the current second	Long
	24-31	Reserved	
pitch	32-35	Pitch in degrees	Float32
roll	36-39	Roll in degrees	Float32
yaw	40-43	Yaw in degrees	Float32
heading	44-47	Heading in degrees	Float32
	48-51	Reserved	

There are two Matlab programs that will read the *.jsf files. The bossReadData.m program will not only read the *.jsf data file but it will also correct for the XYZ location of the hydrophones. The *.jsf files contain many pings so one has to build a data array in order to perform any synthetic aperture array processing scheme. The reference layout of the hydrophones is shown in Figure 6. The mapping of the data array indices to the hydrophones in the ADC Channel data (message 4021) is as follows:

Segment A, Hydrophones 1-20

1, 21, 3, 23, 5, 25, 7, 27, 9, 29, 11, 31, 13, 33, 15, 35, 17, 37, 19, 39

Segment H, Hydrophones 1-20

2, 22, 4, 24, 6, 26, 8, 28, 10, 30, 12, 32, 14, 34, 16, 36, 18, 38, 20, 40

When one ping is read, a data array {data ([1-40],:) }will be generated. The data from hydrophone H5, will be the data in the data array { data (6,:) }. The data from hydrophone A14 will be in the data array { data (33,:) }.

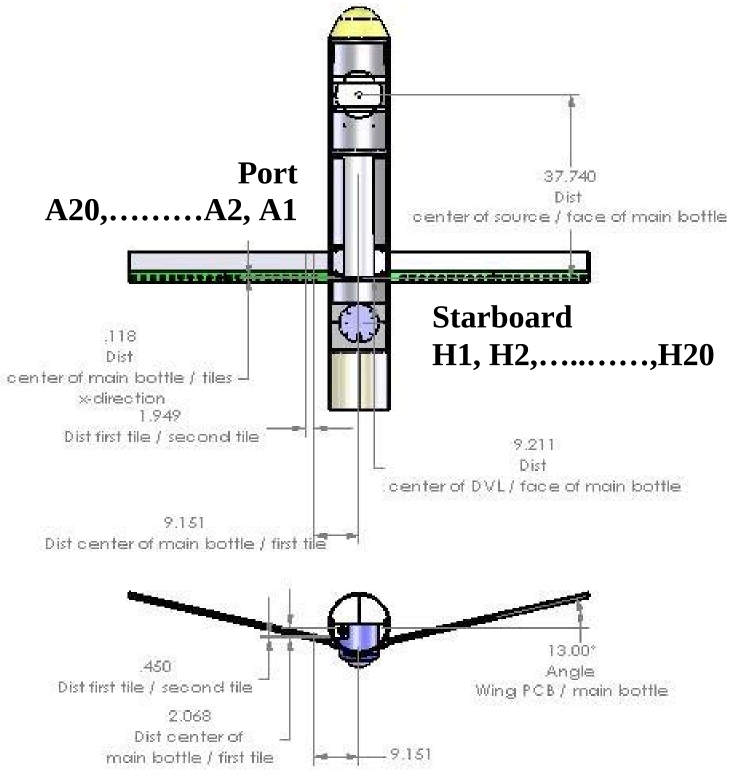
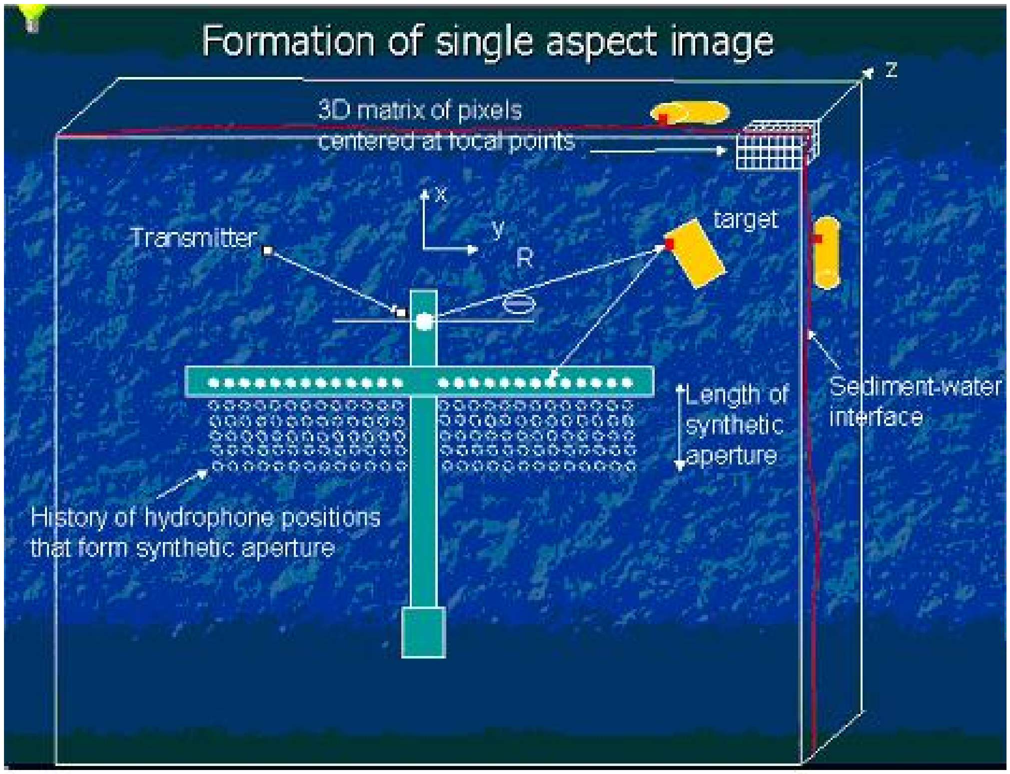


Figure 6. Hydrophone layout in the UUV wings.

The BOSS SAS processing scheme is depicted in Figure 7. Employing the data into the equation for many spatial points, an image can be formed.



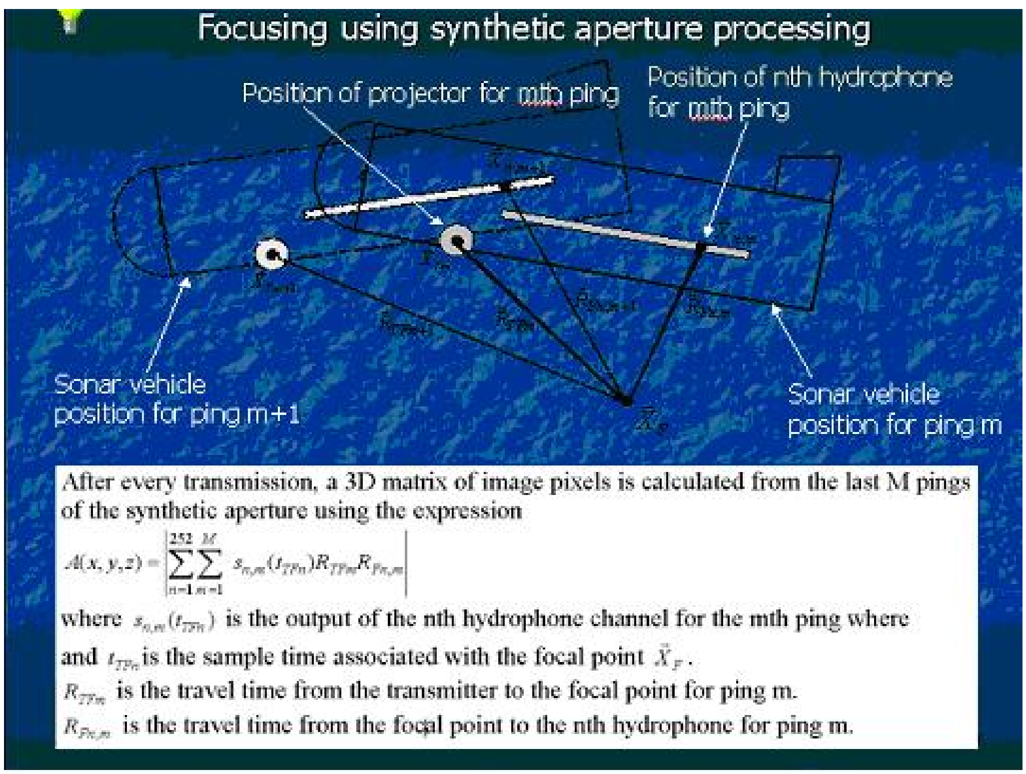


Figure 8. BOSS SAS processing scheme.

Listed below are some references associated with the BOSS systems.

1. “Buried object scanning sonar,” IEEE J. of Oceanic Eng., vol. 26, No. 4, October 2001, pp. 667-689.
2. “Sonar for Multi-Aspect Buried Mine Imaging,” Proceedings, Oceans 2002, October 2002.
3. “Buried Object Scanning Sonar for AUVs”, Proceedings, Oceans 2003, September 2003.