Comparison of Shallow Water Mapping Technologies

Purpose: (1) To develop a resource that participants can refer to for comparative information about shallow water mapping technologies;
(2) to initiate discussion among participants at the workshop about needs, opportunities and challenges for shallow water mapping within their holdings

	Top Advantages & Disadvantages/Limitations			Data types & products: green= "primary product/primary purpose" of this technology; yellow="fair" for this use; red="poor"
Technique/ Technology	prime advantages	limits/disadvantages of technology (e.g. risk, requires support vehicle, etc.	Trade-offs/thresholds	Primary products
Side-scan Sonar	*Sidescan is primary tool for regional mapping in shallow water b/c it has wider swath than multibeam & interferometric in shallow waters <30 m. (more cost-efficient) . Sidescan can achieve swath widths of ~100 - 200 m in depths < 10 m. *Only technology capable of producing continuous coverage imagery of seafloor at all depths. *Sidescan has no angular sector limitations, whereas multibeam has a fixed angular sector.	* Only partial bathymetry achieved. * Geohazards pose risk to sidescan equipment in shallow water. * Boat based operations difficult in 0-10 m depths along open coast due to wave height, submerged rocks, kelp and irregular coastlines . * Requires support vehicle.	* Trade-off between swath width, resolution, survey speed, and financial resources must be considered. Choices will depend on: 1) the size of the area to be surveyed, 2) what resolution of substrate definition is required, and 3) how much time and money is available for the survey. * 100% sidescan coverage optimizes costs/maps large areas, but provides only partial, non-continuous bathymetric coverage (interpolation required). * High frequencies (500kHz to 1MHz) give excellent resolutions but the acoustic energy only travels a short distance (< 100 m). * Sidescan backscatter has more resolution than multibeam, but can't correct for distortions from sensor motion.	* Bottom topography * Substrate type/seafloor geology. *Mapping landscape level attributes including geologic formations, substrates, and circulation patterns *Classify formation, zone, structural environment
Multibeam Sonar	Ability to acquire dense sounding data w/ few tracklines, and simultaneously acquire backscatter imagery using same sensor. Multibeam has dramatically improved ability to acquire continuous high-resolution depth data over wide areas.	*Multibeam is less efficient in shallow water (< 30 m). Time intensive and costly in shallow water due to limitations on swath width. Swath width is only 3-5 x water depth. Narrow swath=more tracklines, time, cost. *Surveying in < 5 m. particularly tough. * Rigorous groundtruthing needed to verify the accuracy of substrate classifications b/c results can vary widely between sites & w/environ. conditions. * Boat based operations difficult in 0-10 m depths along open coast due to wave height, submerged rocks, kelp and irregular coastlines .	* Much more complex and expensive relative to single beam, but benefits in cost per unit effort and resolution can well outweigh the disadvantages. * Swath widths shorten in shallow depth (<5m). * Multibeam backscatter images lack the resolution and detail in sidescan images, but they can be corrected for distortion from unintended sensor motion (e.g. role, pitch, and heave from waves) (not true for sidescan systems) . * Requires support vehicle	*Seafloor morphology/shape of the seafloor/seafloor topography. Bathymetry. * Surficial geology/substrate classification from multibeam backscatter is improving. **Classify formation, zone, structural environment
Interferometric	* Interferometric preferred technique in this workshop for shallow water b/c get sidescan sonar and bathymetry at same time * Ability to acquire dense sounding data w/ few tracklines, and simultaneously acquire backscatter imagery using same sensor. * Same data from interferometric as achieve with multibeam, but swath width is 7-10 x water depth in water depths < 30 m). More areal coverage in less time). * Successful use in water depths < 5 m.	* May not resolve irregular topography as well as multibeam. * Requires a support vehicle. * Similar risks with any system 'over the side'. Less risk with hard-mounted systems (hull mounts, sidemounts, bowmounts).	Pros & cons to multibeam and interferomentric sonars, but both do a quality job of mapping depth (seafloor toporgraphy). * May not resolve irregular topography as well as multibeam, however, USGS has found resolutions still adequate for geologic studies. * Imagery is best at shelf depths >100 m. (use differing frequencies depending on depth).	Seafloor morphology/shape of the seafloor/seafloor topography. Bathymetry. *Mapping landscape level attributes including geologic formations, substrates, and circulation patterns *Classify formation, zone, structural environment
single beam echosounders				* High-resolution bathymetry.
single beam or swath w. bottom classification	* Single beam sonar is a good choice for mapping bathymetry in very shallow water (i.e., less than 3 m.) * Can interface single beam depth sounders with acoustic substrate classifiers to correlate the intensity values from single beam w/seafloor substrate hardness and roughness. *Single beam and RTK GPS mounted on jet ski can map at 15-20 knots.	* Bathymetry is generally either too coarse (postings at > 50m) or inaccurate for fine grain mapping at macro- or micro-habitat scales. * Results difficult to interpret without a lot of groundtruth data. * Risk in 0-10 m open coast areas--boat operations made more difficult/risky by hi waves, submerged rocks, kelp canopy and irregular coastlines. * Requires a support vehicle.		* High-resolution bathymetry. *Mapping landscape level attributes including geologic formations, substrates, and circulation patterns
LiDAR (Light Detection & Ranging Systems)	* Beneficial and efficient in areas that are challenging to reach by boat. * Uniform and dense data in extremely shallow water. Comprehensive coverage * LIDAR is cost effective for surveying large, shallow areas with generally good water clarity. * Many states have good LIDAR coverage. *Simple to interpret features.	*Turbid or otherwise poor-visibility conditions reduce the depth capabilities. *Determining if acoustically distinct areas are different habitats requires ground-truthing. * Factors like water depth, bottom slope, and vegetation can change the acoustic signature from place to place. • EAARL system provides less bathymetry data than SHOALS and potentially inaccurate readings (i.e. doesn't match with single beam sounder measurements and/or no valid returns in shallow water).	* Lidar bathymetry is well established, backscatter is still under development. * In the northeast, LIDAR systems are appropriate for the collection of excellent comprehensive coverage, coastal topography data over large coverage areas. However, LIDAR systems presently have limited use for bathymetry mapping in the northeast region. Turbidity largely restricts LIDAR bathymetry mapping to times of the year when the weather is poor, flights may not be able to run, sea-states may affect the data quality, and/or weather delays may greatly amplify costs. Time of year is a critical concern for LIDAR bathymetry surveying in the Northeast. * Side-looking LIDAR deployed off a ship is cheaper than airborne LIDAR and enables the simultaneous collection of swath bathymetry and topographic data. However, motion sensors are needed to correct both types of data, and there are problems integrating the datasets with interferometric bathymetry data because of vertical datum problems	*Bare-Earth and First-Return Topography; Color-infrared photography *Coastal topography/ elevation data (DEM, upland features, beach width), dune & beach topographic profiles, sediment volumes, shoreline position (berm, upland vegetation edge), landcover, anthropogenic modifications (structures, disturbances, channels, dredge sites), vegetation structure (height, class, size), saltmarsh & SAV change detection, intensity grids, point cloud, contours, waveform data. Multispectral LIDAR provides characteristics of vegetation (saltmarsh, dune, SAV), water features, elevation, slope, aspect, and distance to coastline. *Side-looking/land-based LIDAR systems good for shallow water topography. Maps shape of the surface to a centimeter or less resolution
Airborne Hyperspectral imaging	*Able to rapidly map habitat and vegetation types at meter resolution over vast areas in depths too shallow for survey vessel operations. * More cost effective than swath acoustic techniques, especially in shallow water	*Clear, calm, shallow water is required to obtain high quality data *Turbid or otherwise poor-visibility conditions reduce the depth capabilities and resolving power of Compact Airborne Spectrographic Imagery. * Expensive, still experimental. * Relatively high cost and overall lack of availability to average users.		
Aerial imagery	*Aerial and satellite imagery often offer the best value for intertidal and shallow-subtidal areas b/c broad coverage is possible in a short time. Good complement to acoustic technologies that are more effective (cost and technically) in deeper waters. *Able to collect data across the land-water interface and therefore effective for mapping shallows and complex landscapes (e.g., channels) that would be difficult to navigate via water-borne instruments. *Provides comprehensive data that does not have to be interpolated. * Familiar data type to broad audience and relatively intuitive visual interpretation. * Collected routinely by many agencies; large existing archive.	* Aerial techniques are ineffective in deeper water and their use is limited by turbidity, cloud cover, agitated sea states, sun angle, and tides. However, w/careful planning, effects of these conditions can be minimized. * Photo-signatures can be variable and influenced by water color. * Ground-truthing is required.	While effects of environmental conditions can be minimized w/planning, this will limit flight opportunities and increase costs (survey firms will need to build risk & wait time into their costs). Sea state can be minimized by avoiding windy seasons or surveying after sustained winds. Turbidity can be minimized by avoiding surveys after recent rains/sustained winds. Sun glint can be avoided by collecting imagery when the sun is high.	Maps of landscape level attributes.

Technique/ Technology	bathymetry	backscatter quality/ roughness data	Surficial or subbottom geology	Ease in developing habitat/substrate information from data/amenability to classification	Compatability with other datasets & GIS software	Horizontal/vertical Resolution
Side-scan Sonar	* No. Poor.	* Primary product * Excellent-good	* Primary product; * Provides view of seafloor surface and distribution of surficial sediment (e.g. rock, sand, mud, etc).	Good	* Integrating data done routinely. * Easy to somewhat challenging depending on experience. * Routinely displayed w/in GIS	Typical systems used for nearshore mapping have frequency ranges from 100-500 kHz with resolution as fine as 20 cm. (These are optimum resolutions. Realistic footprint is generally less than optimum; many other considerations such as navigation system used, layback of towfish, etc.)
Multibeam Sonar	* Yes *Primary purpose. *Excellent high-resolution bathymetry·	*Fair. * Note: new models create huge backscatter files (ex: RA found in depths <20m backscatter files = 1GB per 1 lnm depending on system settings)	* Primary product; * Defines seafloor topography	* Fair and improving. * Yes, with backscatter.	* Integrating data done routinely. * Easy to somewhat challenging depending on experience. * Routinely displayed w/in GIS	* Bathymetric data with horizontal postings of <1m. are possible if experienced in multibeam processing. * Vertical resol. is primary concern with bathymetric data - * Data artifacts and poor operating conditions can reduce achievable resolution.
Interferometric	* Can map at 0 m. depths * Does a quality job of mapping depth (seafloor toporgraphy). * Imagery is best at shelf depths >100 m.	* Good. Primary product	* Primary product; * Defines seafloor topography * Exellent-good	Good.	* Integrating data not a problem. Done routinely. * Easy to somewhat challenging depending on experience. * Routinely displayed w/in GIS	Can be within cm's of the horiz. and vertical resolution of multibeam sonars. Bathymetric data with horizontal postings of <1m. are possible if working with someone experienced in processing. Vertical resolution is primary concern with bathymetric data - Data artifacts and poor operating conditions can reduce achievable resolution).
single beam echosounders						
single beam or swath w. bottom classification	* Excellent-good *In very shallow water, eelgrass affects the pulse. Need for system that stores full wave forms rather than just depth picks to remove eelgrass effects. Ability to pick reliable depths in post processing is much higher than in real time. Can detect the canopy height of the eelgrass bed but it can be difficult to discern the eelgrass from the bottom, especially at lower tide stages b/c the eelgrass is closer to the bottom. *Heading into current changes elevation of boat and of transducer. Can be as much as 10 cm offset. Weight of the boat crew can also affect elevation measurements	*No. * Good-poor. * Part of calculation, but not explicit	*Broad scale regional view of seafloor topography	* Good-poor. * Primary design, but results are difficult to interpret on large scales	Corresponding tide monitoring is very important for single beam bathymetry mapping in very shallow waters to enable tidal corrections. Pressure sensors can be used to measure tides, but these are affected by variations in salinity and temperatures because the sensors correct according to density. Wind can also be a major factor in changing from predicted heights.	*bathymetry horizontal position accurate to 3 meters and vertical position accurate to 15 cm. * RTK GPS can increase the horizontal accuracy to the sub-meter level *Vertical accuracy is important in extremely shallow water. Positioning done with RTK GPS allows direct reference to global positioning system. Reported vertical precision < 10 cm.
LiDAR (Light Detection & Ranging Systems)	* Good in high clarity areas. * Limited capabilities in Northeast b/c of turbidity. * USACE SHOALS system better than EAARLS for collecting nearshore bathymetry	* No. poor. * Some systems, not all.		*Simple to interpret features.	* If raw points converted to raster format, most GIS software can be used to perform topographic analysis	
Airborne Hyperspectral imaging	* Poor. * Derived depths possible, not very accurate	* Fair. * No.		* Fair. * Yes, primary purpose. * Emerging technology for classifying benthic habitats in coastal zones. * Ideal for nearshore subtidal habitat mapping in areas with high water clarity	Data requires special image-processing software before they can be imported into GIS	* Very high; meter resolution. * 1:25,000 map accuracy
Aerial imagery	No	None	* Very Limited. * Major shallow geomorphological structures like rock outcrops or shoals can be detected but no sub-surface or deeper water info	*Good. * Imagery is easily interpretable to the unaided eye and the higher resolution digital data does support new semi-automated methods.	* Very compatible through the commonly used GeoTiff and Imagine .img formats	* Normally 0.25m to 1m for landscape level mapping

	Management Transferability		Suitability for conditions:				
Technique/ Technology	ease in converting data into usable products/interpreting products for mgmt purposes	Management purpose for which products are most amenable	Suitability for shallow water mapping depths: (green=suitable for surf zone/0-5 m; yellow=>5m; red=>30	turbidity: (green=can be used in low visibility/hi turbidity);	Surf/high wave conditions: (green=can be used in hi wave conditions)	substrates types or biogenic habitats suited for	Suitability for high currents (green=can be used in high currents)
Side-scan Sonar	* Need geologist and ecologists to work together to define substrate and then habitat. * Does not automatically translate into habitat maps, expertise needed	Habitat mapping, geologic framework studies, seafloor geology (i.e. substrate).	* ~5 - 200 m . Best used in relatively shallow (<50m) flat bottoms. Less effective in depths <5 meters. * Depends on towfish, surface or depth tow, and cable length. * Towfish should be towed @ 10-20% range scale (usually 7-20m water depth)-tether limited.	Turbidity will limit maximum range, but can be used in turbid, low visibility water. Good/fair.	*Fair-poor. * No systems available to remove motion induced distortion from data. *surveys conducted when seas are > 2m produce results of little value.	*Most. * Can be used in a variety of bottom types to map surficial "sediment" distrib, but must be accompanied by ground-truth to define substrate and habitat. Best for relatively flat regions.	towfish affected by currents
Multibeam Sonar	* Need geologist and ecologists to interpret and generate habitat maps. * Backscatter needed for habitat maps. * Easy to medium difficulty.	Dredging projects, rivers, harbor inspection surveys, oil field engineering, oceanographic research projects, environmental studies, mine detection, obstacle avoidance	* 0 - 3000 (can survey to the 0-1m curve with a tilted transducer). * Varies by system & frequency dependent. * Shallower the water the denser the concentration of data.	* Yes, but sound velocity errors will have a greater impact on data. * Can be used in turbid low visibility conditions.	* Yes, if safe to maneuver vessel. * Fair, limited by endurance of the platform. Hull or pole mount.	* Can be used on all bottom types. * Higher resolution with higher frequency systems. * Must be accompanied by ground-truth to define substrate and habitat.	hull mount less susceptible to currents, towfish susceptible to positional errors
Interferometric	Easy to medium difficulty. Need geologist, biologist, ecologists to interpret and generate habitat maps.	NOAA Hydrographic Office is utilizing interferometric data to update charts. Dredging projects, rivers, harbor inspection surveys, oil field engineering, oceanographic research projects, environmental studies, mine detection, obstacle avoidance	Systems available in variety of frequencies which enables work in shallow to deep. USGS has routinely used in waters 0 - >100 m. Imagery is best in water between 7-20m depth. Depends on frequency, towfish, surface or depth tow, cable length.	fair / good. can be used in turbid low vis water. Not affected.	fair. limited by endurance of the platform. Hull or pole mount. Usually towed subsurface.	Can be used on all bottom types. May not resolve irregular seafloor as well as multibeam, however, still adequate for habitat studies.	hull mount less susceptible to currents, towfish susceptible to positional errors
single beam echosounders							
single beam or swath w. bottom classification	* Trained technicians will be required to interpret data. * Difficult to interpret, except perhaps on very small scale areas with lots of ground truth data. *TraceEd (developed by Semme Dijkstra) is a processing software for single beam data of wave form to deal with eelgrass and very shallow water.	Mapping sand ridges; determining sedimentation rates and patterns; eelgrass canaopy mapping; high resolution bathymetry map provides a baseline to determine changes in bathymetry and provides a physiographic baseline for future physical and biological studies; connect single beam & side-facing LIDAR surveys to determine shoreface architecture	* Varies by system but generally 1-150m water depth. *3-4 m depth used as the cutoff for single beam in Fire Island example	* Yes, but sound velocity errors will have a greater impact on data. * Good. Can be used in turbid low vis water. Not affected.	*Good. *Limited by endurance of the platform. Hull or pole mount. * Yes, if safe to maneuver vessle	*Sand, gravel. *Can be used on all bottom types. * Does not do well in coral environments (mostly hard). * Less than 50% accuracy.	hull or pole mount can withstand high currents
LiDAR (Light Detection & Ranging Systems)	* No. Does not automatically translate into habitat maps, expertise needed	Biannual cross-island (dune & beach) topographic profile elevations help to describe and evaluate trends in island topographic relief and storm-driven change. High-resolution LIDAR-derived DEM's to calculate sediment volumes for complete coverage between profiles. • Elevation data needed for long-term monitoring of coastal change • measuring littoral sediment movement • Monitoring estuarine basins that are part diked tidelands for hydrodynamic modeling/decision-making related to tidal restoration • Dune migration and deflation plain wetlands • Vegetation change detection (salt marsh and SAV) • Short-term management decisions about public facilities. *Elevation data can inform strategies to address sea level risemap. *Detect objects (mines, fish schools, etc.) in the water column. * Geological mapping of the seafoor, benthic habitat mapping, and subaqueous soil delineation. *shoreface architecture	* 0-20m typically, * If very clear up to 50m. * Extremely shallow. *In turbid water only successful to depths of two to three times the visible depth. * Varies, generally less than ~30 m. Under ideal conditions, up to 60 m penetration is possible	* Turbidity will limit maximum depth range. *Requires good water clarity. *Definitely a problem	* Results dependent on wave conditons	* Some issues with lidar in hard substrates.	
Airborne Hyperspectral imaging	* Generally done manually, expertise & ground-truth data required. * Interpreted products designed for management use, but classification schemes and interpetation may or may not meet needs.	Monitoring for oil spills, pulp mill effluent, schools of fish and coastal zone water flow. Marsh tidal restrictions; Oil detection; vegetation species mapping; water quality assessment; geologic mapping. (CASI) Maping vegetation, substrate, phytoplankton abundance, thermal and pollution plumes. Used to map benthic algae, substrate type and benthic habitats in shallow coastal waters. Habitat features of intertidal marshes, shallow estuarine systems.	* Varies, generally less than ~30 m * Shallow. *Generally only effective within secchi disk depths.	Requires high clarity. Definitely a problem	*Calm. * Very affected.	Most	
Aerial imagery	* Traditionally done manually, but semi-automated methods are moving into the operational realm. * Ground-truth data required. * Yes. Interpreted products designed for management use, but classification schemes and interpetation may or may not meet needs.	Habitat mapping, shoreline change. Seagrass extent and change detection. Oyster reef detection. Spatial relationships between shallow habitats and adjacent terrestrial stessors. Mapping coastal emergent marsh interior structure and morphology, seagrass meadows, intertidal and shallow-subtidal shellfish beds(<2 m), macro algae (kelp canopy), shoreline condition (e.g., rocky shores, beaches, artificial), assessing accretion	* Varies, generally less than ~30 m * Above MLLW. * Very shallow.	*Requires high clarity. * Turbidity is definitely a problem	* Fair * Only limited surface waves can be tolerated.	Intertidal and near sub-tidal. Macroalgae, shellfish reef, shore-zone conditions, emergent marsh, seagrasses	

	Costs		For more info:	
Technique/ Technology	Surveying costs (green=low/tens of thousands; yellow=medium $?-$?; red=high; hundreds of thousands). Also processing time/costs if available.	Drivers of cost (influences on cost)	Experts in this technique	Workshop speakers covering the technology
Side-scan Sonar	Ranges provided: * $10-$50K * $150 - $250K (NOAA Hydro Survey Division).	* Survey costs dependent on 1) research or management objectives; 2) extent & location of survey area; 3) identified products; 4) size of towfish. * Processing costs will depend on amount & quality of data collected, etc.	LT Jake Yoos, NOAA/OCS, USGS Woods Hole, John Ladd	Paul Gayes, Thomas Grothues, David Twichell, Walter Barnhardt, John King
Multibeam Sonar	* $75 - $300K. Typically $300K. * Generally expensive. More expensive in shallow water b/c swath widths decrease.	*Depends upon frequency, research/mgt. objectives, extent of the survey area, products, depth. * Processing costs built into project cost & depend on the amount of data collected, quality of data collected, etc.	USGS Coastal and Marine Program, Woods Hole, MA; NOAA/OCS, Joyce Miller (NOAA Coral Reef Ecosystem Division)	Paul Gayes, Walter Barnhardt
Interferometric	* (See matrix of costs & survey days provided by John King for 100% bathy & sidescan coverage) * $125K. Large range, depending upon size of fish. Completely dependent on 1) objectives of the research and/or management activity, 2) extent of the survey area and 3) products	Built into project cost, will depend on the amount of data collected, quality of data collected, etc.	USGS Coastal and Marine Program, Woods Hole, MA; UNH, CCOM; University of New Brunswick Ocean Mapping Group; Dr. Margo Edwards	John King, David Twichell, Walter Barnhardt
single beam echosounders				
single beam or swath w. bottom classification	* $5 - $10K. $20K. * Relatively low cost.		USGS Coastal and Marine Geology Program, Woods Hole, MA; Jim Jacobson - Chief Survey Tech, Rainier, NOAA/OCS	Larry Ward, Paul Gayes (Fire Island Shelf Sand Ridges & SC Erosion Study), David Twichell, Tom Grothues (AUV-mounted single beam).
LiDAR (Light Detection & Ranging Systems)	* Can be 25% of multibeam costs in less than 10-15 m depths. * 1st tier= million dollar instruments *~ $1,000 to $2,000 per square mile for 2 to 3-meter postings. Includes flight, LIDAR collection, post processing, and delivery. *Typical NOAA OCS Lidar projects are $1.5 million. * SHOALS system costs $8,000-$10,000 US per square mile for raw & processed x,y,z data (approximately $3100-$3900 per square km), depending on whether dGPS or RTK GPS is used.	Cost can vary depending on size of project, horizontal postings (point density), and project location. Dependent on turbidity, depth, etc. More expensive if RTK GPS is used.	NPS data requests can be made to Dennis Skidds (Dennis_Skidds@nps.gov); Sources of LIDAR data: (1) USGS/NASA LIDAR acquisition 1998-2005, 2010-- http://lidar.cr.usgs.gov/ ; (2) Army Corps of Engineers bathymetry LIDAR data (ACOE JALBTCX 2000, 2007, 2010)=SHOALS data; (3) NOAA SHOALS LIDAR data available from Digital Coast (http://csc-s-maps-q.csc.noaa.gov/dataviewer/viewer.html?keyword=Bottom%20Reflectance). Data available: 1999 Fall East Coast; 2000 Fall East Coast; 2004 Ct Coastline; 2004 Maine Coastline; 2005 ASACE Topo/Bathy; 2007 USACE New England Topo/Bathy; 2008 NGS NH; (4) ACOE CHARTS (Compact Hydrographic Airborne Rapid Total Survey). David Scharff - Data Acquisition and Control Branch - Headquarters; Mr. Tim Battista;	Mark Adams
Airborne Hyperspectral imaging	* approximately $3100-$3900/ km2 for CASI data acquisition and processing (Kvitek et al. 1999). * More cost effective than swath acoustic techniques, especially in shallow water	Cost can vary depending on size of project, environmental constraints, spatial resolution, spectral resolution and level of post-processing.	Dr. Eric Hockberg	Mark Adams
Aerial imagery	* ~$200-$682/sq. mile	* Drivers of aerial data acquisition costs: level of tidal control, ferry/staging time, sensor selection, flight line complexity, spatial resolution, spatial accuracy, coverage area. * Spatial resolution. * Remoteness, * Prevailing weather conditions, * Project area size and spatial complexity. * Sensor type. * Tidal requirements * Drivers of mapping cost: classification detail, mapping method, required accuracy, coverage area, minimum mapping unit.	Mike Aslaksen - Remote Sensing Division (NOAA)	Mark Finkbeiner

Satellite imagery/remote sensing	* Aerial and satellite imagery often offer the best value for intertidal and shallow-subtidal areas due to the broad coverage that is possible in a short time. With planning, the limitations of these techniques can be minimized. Good complement to acoustic technologies that are more effective (cost and technically) in the deeper waters. *Able to collect data across the land-water interface and therefore is effective for mapping shallow waters and complex landscapes (e.g., channels) that would be difficult to navigate via water-borne instrumentation. *Can achieve broad coverage and provide comprehensive data that does not have to be interpolated. * Frequent revisit times possible * Can cover large areas of shallow, estuarine habitats.	* Seldom possible to acquire satellite imagery under the appropriate conditions for effective benthic mapping. * Cloud cover, turbidity, sun glare, agitated sea states can cause interference and limit use. However, w/careful planning, effects of these conditions can be minimized. * May face licensing restrictions. * Satellite techniques are ineffective in deeper water			*Poor. *Some capability based on light extinction, but not operational	None	* Very Limited. * Major shallow geomorphological structures like rock outcrops or shoals can be detected but no sub-surface or deeper water info	*Good. * Multispectral imaging has been used to differentiate habitat types like sand, seagrass, coral, where aerial photography unavailable	* Fair. * May require some translation from original image storage format but often available in GeoTIFF format as well.	* Satellite resolution is increasing dramatically * High end satellite multispectral sensors (e.g. Geoeye, Orbview, Ikonos, Worldview, QuickBird, etc.) provide 1-2 meters resolutions. Higher, submeter resolutions that you saw listed are just for black and white, not multi-spectral.	* Automated methods slightly more effective here due to calibrated data. * Ground-truth data required * Interpreted products designed for management use, but classification schemes and interpretation may or may not meet needs.	Determining coastal emergent marsh interior structure and morphology, seagrass meadows, intertidal and shallow-subtidal shellfish beds(<2 m), macro algae (kelp canopy), shoreline condition (e.g., rocky shores, beaches, artificial), assessing accretion. Land use change. For land acqusition initiatives.	* Varies, generally less than ~30 m * shallow.	* High clarity/very low turbidity necessary. * Definitely a problem	* Fair * Only limited surface waves can be tolerated.	Intertidal and near sub-tidal. Macroalgae, shellfish reef, shore-zone conditions, emergent marsh, seagrasses		* ~$300-$500/sq. mile. See Mark Finkbeiner presentation	* Project area size. * Level of processing desired. * Licensing restrictions * Drivers of satellite data acquisition costs: licensing, reseller, rectification order, vintage, specific tasking (off-nadir, cloud restrictions, etc.), coverage area * Drivers of mapping cost: classification detail, mapping method, required accuracy, coverage area, minimum mapping unit.	Steve Rohmann - NOAA Sanctuaries	Mark Finkbainer
AUV platforms designed for shallow water work (e.g. REMS 100 or Ecomapper)	* Can reach hazardous or difficult areas more easily than manned platforms * Can install a variety of sensors to address research/management objectives * Can be hand launched from beach * No cables * Tends bottom * Navigation not offset from sensors * May increase survey vessel footprint without addition crew	* Range may be a limiting factor. * May require support vehicle for launch and recovery. * Geohazard risks to equipment in high relief bottom/structure. * Floating or SAV poses entanglement/prop fouling hazard	* Number of sensors moderately influences survey time as function of power draw. * Best path may be compromise between optimum for different sensor requirements. * Navigation type choice (accurate trilateration from ranging beacons vs less accurate dead reckoning) is a compromise between survey path aspect ratio and precision needs.	Sidescan mosaics, surficial topography, depth (height over bottom), etc. Depends on sensors on AUV, but can be used to map benthic sediment structure, reef structure, anthropogenic artifacts, hydrography, benthic and nekton biota (e.g., worm tubes, fish schools, fish tracking).	* Good. * Depends upon sensors on AUV, Multibeam possible.	* Good. Depends on sensors on AUV. * Yes, if equipped w/ proper instrumentation (ex., sidescan, etc.)	* Depends upon sensors	Good. Depends on sensor package	Compatible	Depends on path and mission commands, may be compromised by orthogonal mission needs	* Sensor dependent, generally direct output as text, csv (Excel), or Matlab file within minutes of recovery, time stamped for integration	habitat mapping, hydrography, water quality, fish tracking. Navy mine surveys.	* 3-100m: for shallow water AUVs. * There are AUVs designed for deep water work with different constraints and capabilities than those listed here	*Turbidity not an issue for platform, but may lower navigation beacon range so more are required	* Fair. * Tolerates waves during launch and mission, but recovery limited to lower sea state * Depends on recovery/launch system and working environment * High $$ risk if AUV aborts and drifts into surf	* Moist. *Depends, does AUV have avoidance system? If no, then low relief or higher above-bottom altitude and consequent lower resolution *Very soft muds hinder ADCP bottom lock, are mitigated by compromising working altitude to provide a good echo return (lock), loose SAV hinders propulsion	Usually less powerful than vessels	* Depends on what is equipped with * Typical sidescan w/ $300k * Depends upon AUV	* High R&D costs, low private sector competition * Sensor dependent * But, may replace or extend capability of more expensive ship * One-stop shop for multiple integrated data streams * Rent is an option * Choice when high quality sidescan is necessary	Steve Brodet - Hydrographic Systems Technology Program; John.Rooney@noaa.gov	Thomas Grothues, Michael De Luca, David Twichell (ASV)
Laser Line Scan	*Provides a resolution midway between that provided by video and still imagery, but at a much higher coverage rate and with much better penetrating capabilities (up to four or five times that of video * Potential resolution is much better than that provided by sidescan sonar, as fine as 1 mm	* water clarity limits viewing altitude, and thus swath width and resolution possible * Few LLS units available, and are expensive w. operational issues	* High cost & still experimental, but potential to dramatically increase image resolution over broad survey areas.		* Poor. * Not unless multibeam on same platform	* Fair. *No.		* Yes. * Fair.		* Potential resolution is much better than that provided by sidescan sonar, as fine as 1 mm	* Requires high level of expertise to process data into product.		* 3-1500 m. Depends on vehicle, tow cable etc. * Penetrating capabilities up to four or five times that of video	* Not affected as much as standard photography	* Yes	* Most	Swifish affected by currents	* Very expensive when compared to other photography		SAIC	
Still photography	Well established technique			groundtruthing technique for substrate type, biology s	* Poor. * No.	* Poor. * No.		* Poor. * Yes, but very limited scale			* Availability of mosaics, well documented locations		* Depends on how deployed	Yes, clarity needed	?	Most	* Depends on how deployed	Low			Walter Barnhardt
Underwater Video	Well established technique			*Habitat consisting of an abiotic component (substrate) and biotic component (functional groups) and habitat attributes of substrate, rooted vegetation, water column, and faunal communities/population patterns can be mapped with underwater imagery or to groundtruth acoustic backscatter	* Poor. * No.	* Poor. *No.		* Excellent-poor. * Yes, mosaicing needed.			* Availability of mosaics, well documented locations		* Limited by diver or tether length. * Depends on housing	* Limited to good vis. * Yes	* Not affected as much as standard photography	Most	* Limited by diver or tether length. * Depends on housing	Low; $250/day (does not include cost of survey vessel and crew, which equaled $3665/day in John King's example)			Paul Gayes, John King, Walter Barnhardt
Seismic reflection/chirp sub-bottom profiling	Well established technique.		*Higher frequencies (provide the highest resolution, but are limited in amount of penetration below the sea floor. * Lower frequencies yield more penetration, but less resolution. * Decision is determined primarily by the water depth and the type of substrate.	sediment thickness/structure and stratigraphy under the seafloor.	* Poor. *Not primary purpose. *Possible w/chirp seismic systems.	* No. * Poor. * Subsurface structure is primary product	* Critical component to defining seafloor geology/framework (stratigraphy)	* Integrating with surficial data (bathy, sonar) can help to define substrate/habitat. * Excellent for subbottom interpretation	* Interpretive results routinely integrated with other geophysical data and within GIS	* Depends on the environment (sediment type (sand, mud, rock, etc)) and system used (various frequencies and systems available)	*Hard to interpret. * Need expert to interpret (geologists).	Surficial sediment thickness data is sought to identify beach nourishment material, pipe laying areas, and areas for bottling structures. Used for determining resource management, beach nourishment, critical habitat areas, and to provide baseline data for site specific studies. Used routinely in geologic community for seafloor mapping studies, coastal erosion, geohazards, sea-level rise, coastal evolution, sand/gravel resource, geohazards studies.Well established in oil industry for identification of oil deposits, faults, etc.	* Varies. * Shallow - deep. Varies depending on fish	*Good. Not affected.	*Good. Towed arrays. * Yes, launching. Towed arrays and composite systems (source and receiver in one tow body)	*Sub structure. * Better for soft environments, may not penetrate hard		*$20k - $50K. * Relatively high. * Chirp–Moderate.	* Cost will depend on objectives of scientific/management goals and study size.	USGS; HYPACK	Walter Barnhardt, David Twichell, Paul Gayes, John King
Vibracoring				Primary product of all grab samples/cores is sediment grain size.	poor	fair		fair														Paul Gayes (John King?)
SPI (sediment profile imagery)	*Captures infaunal presence, sediment structure, sediment/water interface. Useful for environmental quality assessments *SPI can perform well for groundtruthing in algae blooms/high turbidity when video technologies fail.	Point data thus limited observations. Instrument is expensive and cumbersome to deploy (requires winching).	May require grab sampling as an ancillary data set.	*Groundtruthing *Faunal communities/population patterns can be mapped with SPI *If you don't need specific grain size or species level information, can define substrate, rooted vegetation, water column with SPI camera	* Fair. Not part of this technology but often captured during deployment	* Surface rugosity can be determined but only over a limited area	*Good assessment method for this.	* Requires relatively high levels of expertise from limited pool of experts	* Easily incorporated as point data as GPS coordinates are normally collected with the data.	* 0.25m	Not easily transformable to management use.	Sediment and environmental quality assessments & biodiversity assessments. Captures infaunal presence, sediment structure, sediment/water interface.	*Well suited and in fact performs better in shallow water than deep.	* Not a limiting factor.	* Can be a limiting factor during deployment	Ideal for soft substrates. Seagrass, shellfish, infauna, detritus, macroalgae, bacterial mats	* Can be a limiting factor during deployment	$350/day (does not include cost of survey vessel and crew, which equaled $3665/day in John King's example)		Bob Diaz, Giancarlo Cicchetti;	John King
Synthetic aperature sonar																						

Other Factors to Consider						For more info:
Technique/ Technology	longevity of the data/interval needed for resurvey	susceptibility to fouling (green=not susceptible or n/a;	launching condition required (visibility, currents, # personnel)	How data can support education and outreach	Datums most commonly used with this technique	Websites/References (also see references document)
Side-scan Sonar	Good longevity;long time; Depends on type of substrate, change potential	Not susceptible. Some susceptibility. Transducer faces should be cleaned appx 1/year. Yes (NOAA Hydro Surveys)	Requires good launching condition. 2-3 personnel to launch/recover. Depends on type of sidescan.			http://woodshole.er.usgs.gov/operations/sfmapping/
Multibeam Sonar	variable answers--good longevity (MJ) vs. short - medium time (HO). Depends on type of substrate, change potential	No. somewhat. Yes. transducer faces should be clean appx 1/year	Yes, to launch boat. n/a (fixed mount). if the system is hull mounted no personnel are required for launch/recovery. Hull mounted.			http://woodshole.er.usgs.gov/operations/sfmapping/; http://www.reson.com/; www.soest.hawaii.edu/pibhmc
Interferometric	good longevity (MJ)/short - medium time (HO). Depends on type of substrate, change potential	no/yes? Transducer faces should be clean appx 1/year.	good - towed, none for fixed mount. if the system is hull mounted no personnel are required for launch/recovery. Depends on type of vehicle			woodshole.er.usgs.gov; http://woodshole.er.usgs.gov/operations/sfmapping/
single beam (QTC view, RoxAnn)	variable answers: good longevity (MJ) vs. short - medium time. Depends on type of substrate, change potential	no/no/yes? transducer faces should be clean appx 1/year	good. if the system is hull mounted no personnel are required for launch/recovery. Hull mounted. Yes, to launch boat			http://www.csc.noaa.gov/crs/rs_apps/sensors/single_beam.htm; woodshole.er.usgs.gov; woodshole.er.usgs.gov/operations/sfmapping/
LiDAR (Light Detectino & Ranging Systems	short - medium time. Depends on type of substrate, change potential	No. No.	Airborne. Yes, airport			http://www.csc.noaa.gov/crs/rs_apps/sensors/lidar.htm; http://ccma.nos.noaa.gov/about/biogeography/;
Airborne Hyperspectral/Multispectral imaging	Depends on type of substrate, change potential	n/a. No.	Airborne or satellite based			
Aerial photography	Depends on type of substrate, change potential	No. No.	Airborne. Yes, airport			
Satellite photography	Depends on type of substrate, change potential	n/a. No.	None			http://www.csc.noaa.gov/benthic/mapping/techniques/sensors/satellites.htm
AUV platforms	Depends…..assume 8-12 for most AUVs. Depends on type of substrate, change potential	Possibly. No.	Yes.			www.soest.hawaii.edu/pibhmc
Laser Line Scan		Yes	Yes			http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T8F-47PPGPB-2&_user=1346706&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=1015783396&_rerunOrigin=google&_acct=C000052397&_version=1&_urlVersion=0&_userid=1346706&md5=e2cf1dbb
Still photography	Depends on type of substrate, change potential	Yes	Divers, tow sleds			
Video photography	excellent. Depends on type of substrate, change potential	yes	Divers, tow sleds			
Seismic reflection/chirp sub-bottom profiling	long. Depends on type of substrate, change potential	no. Some.	good. Yes. Depends on type of tow body			
Vibracoring	Depends on type of substrate, change potential	Yes				
SPI (sediment profile imagery)			Boat launch requred			
Synthetic aperature sonar						