Acoustic Recording System: A portable hardware system for shipboard passive acoustic monitoring of cetaceans using a towed hydrophone array

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Technological advances in both software and hardware have lead to dramatic improvements in systems used for passive acoustic monitoring (PAM) of cetaceans from a variety of platforms. While these advances have vastly improved the quality and quantity of data, the rapid evolution of hardware and software have made it difficult to allow for standardization and collaboration between researchers. Recently, government scientists responsible for PAM of cetaceans have been coordinating efforts in an attempt to standardize methods, including hardware and software, to allow for collaboration and comparison of results. In addition, standardization of methods will allow the various organizations to make the most of limited resources. One component of this standardization was to create a portable acoustic recording system that would be the primary hardware package for standard shipboard surveys using towed hydrophone systems and would allow recordings from the full range of cetacean sounds (up to 160 kHz).

Specifically, the objective of this project was to create a simple, compact Acoustic Recording System (ARS) that would include:

- A rugged, portable rack-mounted case
- Access to 'clean' 12v power; switchable to 12v battery power.
- Amplifier with high-pass filter, multiple outputs (including headphone)
- Audio interface for mid- and high-frequency recording options
- Low-power computer and monitor for digital recording
- GPS

To this end, in 2010 Southwest Fisheries Science Center designed and tested the 'ARS' during a shipboard survey of the Hawaiian Islands. This report includes hardware specifications for the original design, problems encountered during the field testing, and suggested design for future ARS. Our goal is that this ARS system will be adopted by most (if not all) NOAA science centers for their standard shipboard towed hydrophone systems; Pacific Islands Fisheries Science Center (PIFSC) has built their first ARS following our suggestions.

Original ARS Design

Three Acoustic Recording Systems (ARS) were built with the same basic design and some differences in certain hardware configurations. All the hardware devices, including make and model, are given in Table 1. A bandpass filter was included on ARS-3 to provide an option for an anti-alias filter; there was no mid-frequency (192 kHz) audio interface on this ARS. The ARS-2 included two mid-frequency audio interfaces (Motu Traveller). All the components (except the transformer) were selected to run on 12v DC power.

Four components were not designed to be rack-mounted (computer, GPS, fuseblock, and NI-DAQ). These components were mounted on a ½" plastic base (marineboard) which was mounted on full-extension drawer slides for easier access.

Table 1. List of components for ARS Design. Not all components were used on all ARS.

EQUIPMENT NAME	Make	Model	Comments
Portable Rack-Mounted Box	Gator	GAGRR 10L	
Bandpass Filter	Avens	AP-2880-5-R	
Linear Power Supply	Astron	RM-20M-BB	
Amplifier	Magrec	(custom)	(specifications provided in text)
Audio Interface (192kHz)	Motu	Traveller-MK3	
Audio Interface (> 192kHz)	NI-DAQ	USB-6251 BNC	
GARMIN GPS	Garmin	GPSMap 441	plus antennae and long extension cable
Fuse Box	Blue Sea Systems	5015	
Fanless Computer	Logisys	LG-P110FH1	(specifications provided in text)

a) Front View ARS-3 b) Back View ARS-3

Figure 1. Front (a) and back (b) view of ARS-3, including (from top to bottom) Avens bandpass filter, Astron power supply, Magrec amplifier, Ni-DAQ audio interface, Garmin GPS, and Logisys computer.

a) Front View ARS-2 b) Back View ARS-2

Figure 2. Front (a) and back (b) view of ARS-2, including (from top to bottom) Astron power supply, Magrec amplifier, two Motu Traveller audio interfaces, Ni-DAQ audio interface, Garmin GPS, and Logisys computer.

ARS Field Test

Three variations of the ARS were built and field tested during a shipboard survey in 2010. A brief explanation of problems encountered and suggestions for future ARS designs are provided for each hardware component of the ARS. There were no problems with the rack-mounted box, GPS, or fuse box; these are not discussed in this section. A suggested design for future ARS is provided in the Appendix, including a complete list of hardware components and a few particulars regarding building the units.

Power Supply: One of the goals of the ARS was to provide clean 12v power supply to the hardware to minimize electrical noise associated with the ships' power supply. The Astron linear power supply was found to be sufficient on the R/V McArthur, where noise associated with the ships power supply were less problematic than on the R/V Oscar Elton Sette. The noise associated with ships power on the Sette was too severe to be used at any point. It is suggested that the noise level associated with the ships power be assessed for each vessel, and addressed accordingly. Some vessels may work well with a 12v power transformer such as the Astron, some vessels may require completely independent 12v power supply using clean battery power.

Amplifier: The Magrec HP27[1] is a custom-built stereo amplifier that allows a high-pass filter with an adjustable gain and multiple outputs. The Magrec also provided input for a depth sensor. An early version of the Magrec (Magrec-1) included a single option for high-pass filter (20kHz) to maximize the singal-to-noise ratio (SNR) for detection of high-frequency signals from beaked whales and porpoise. We found that this limited our options, and Magrec-2 and -3 were designed to allow for variable high-pass filtering and various gain control for each channel. We

[1] Available from Ecologic Ltd, U.K. http://ecologicuk.co.uk/Equipment.htm

found that three independent outputs per channel was sufficient; however, we suggest that future designs include independent gain control for each channel.

Audio Interface (Mid-Frequency 192 kHz): A Motu Traveller was used as an audio-interface for mid-frequency sampling at 192 kHz. The benefits of the Motu are that it provides an internal low-pass filter set at the Nyquist frequency. This allows for recording at the selected sampling rate without additional anti-aliasing filters (which can be expensive). Significant problems were encountered with the Motu including: problematic software setup, issues with the computer recognizing the Motu which required frequent reboot or re-installation, and occasional unexplained automatic changes to the gain and sampling rate. Any one of these problems would be unacceptable, the combination of the three requires us to examine alternatives. Northeast Fisheries Science Center (NEFSC) has had excellent success using 'Fireface' fire-wire-based audio interface. This has been field-tested during their east-coast surveys, and no problems were encountered. Fireface does not have an internal anti-aliasing filtration; however, this could be rectified by either including a high-quality filter such as the Avens, or by sampling at a rate that is greater than the frequency response of the hydrophones. Also, Fireface has a USB/Firewire version (UFX), a USB-only version (UC), and a 2-channel USB version ('Babyface') of their audio interface, . We have not yet tested any of these USB interfaces, but USB interfaces might be more robust than Firewire in some versions of Windows.

Audio Interface (High-Frequency >192 kHz): The National Instruments Data Acquisition Board (NI-DAQ) acts as a sound-card with multiple channels and specific selection of sampling rate. These components have been used extensively in the field, with few problems. NI-DAQ boards do not have a filtering system; therefore, an anti-aliasing filter must be used unless sampling is greater than the frequency response of the hydrophone. Also, we have noted that there can be some electrical noise 'leaking' from uncapped terminals. We suggest purchasing and applying terminal caps to all unused terminals on the NI-DAQ.

Bandpass Filter: The Avens bandpass filter was included in one of the ARS, to provide an option for filtering at the Nyquist frequency to avoid aliasing. ARS that used the Motu did not need this filtering (due to the internal anti-aliasing filters), and the NI-DAQ sampled at 500 kHz, providing ample sampling above the frequency response of the hydrophones. In our experience, only high-quality filters should be used for anti-alias filtering, and high quality filters are prohibitively expensive. The high-quality Avens filter used here had been in our inventory for years, but we have found that the technology has improved to the point where we are able to sample at very high frequencies (500 kHz) and record to digital media without great expense. We suggest that these methods would most likely be preferable to investing in high-quality expensive filtering hardware.

Conclusions

The ARS designed and built by SWFSC allowed for relatively easy shipping overseas as well as shipboard setup. A 12v powered system decreased internal noise associated with ships' power, although some vessels with extremely noisy ships power may need to completely isolate their acoustic systems. Field-testing of these acoustic recordings systems showed them to be highly functional, with some suggested modifications. The suggested hardware inventory and design for future ARS packages are given in the Appendix.

Appendix 1

ARS Suggested Design

The Acoustic Recording System (ARS) consists of a portable rack-mounted case containing a power supply, amplifier, GPS, computer, and mid- and high-frequency audio interfaces (Table 1, Figure 1). Ships' AC power is provided to the Astron power supply, which then provides 12v power to the other hardware devices via the fuse box (Figure 2). The Astron must be modified to provide 12v power (Figure 3). Power cables to all units are modified to allow direct connection to a fuse box (Figure 4, 5). The amperage of the fuse will vary per device (see device manuals for specifications). We also suggest minor modifications to the NI-DAQ to decrease noise found to 'leak' between terminals (Figure 6). A support was built to provide support to hold the computer, NI-DAQ, GPS, and fuse box; we mounted our support on a tray to provide easy access (Figure 7). The tray had a simple locking mechanism (Figure 7).

Table 1. Suggested hardware components (make/model) to be used in acoustic recording systems (ARS) for shipboard surveys using towed hydrophones for passive acoustic monitoring of cetaceans.

EQUIPMENT	Make	Model	Comments
Portable Rack-Mounted Box	Gator	GAGRR 10L	
Linear Power Supply	Astron	RM-20M-BB	* Optional, depending on power supply and noise issues
Amplifier	Magrec	(custom)	(specifications provided in text)
Audio Interface (192kHz)	Fireface	800	(several other options available)
Audio Interface (> 192kHz)	NI-DAQ	USB-6251 BNC	
GPS	Garmin	GPSMap 441	plus antennae and long extension cable
Fuse Box	Blue Sea Systems	5015	
Computer	Logisys	LG-P110FH1	(specifications provided in text)

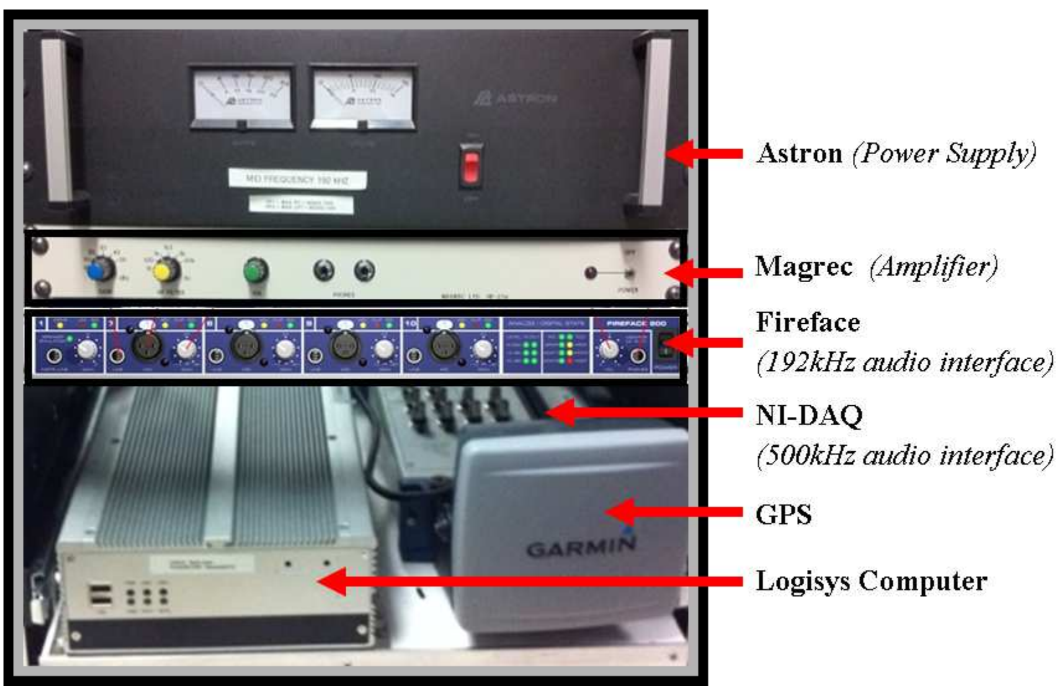

Figure 1. Suggested ARS Setup including: Astron power supply, Magrec amplifier, Fireface and NI-DAQ audio interface, GPS, and Logisys computer.

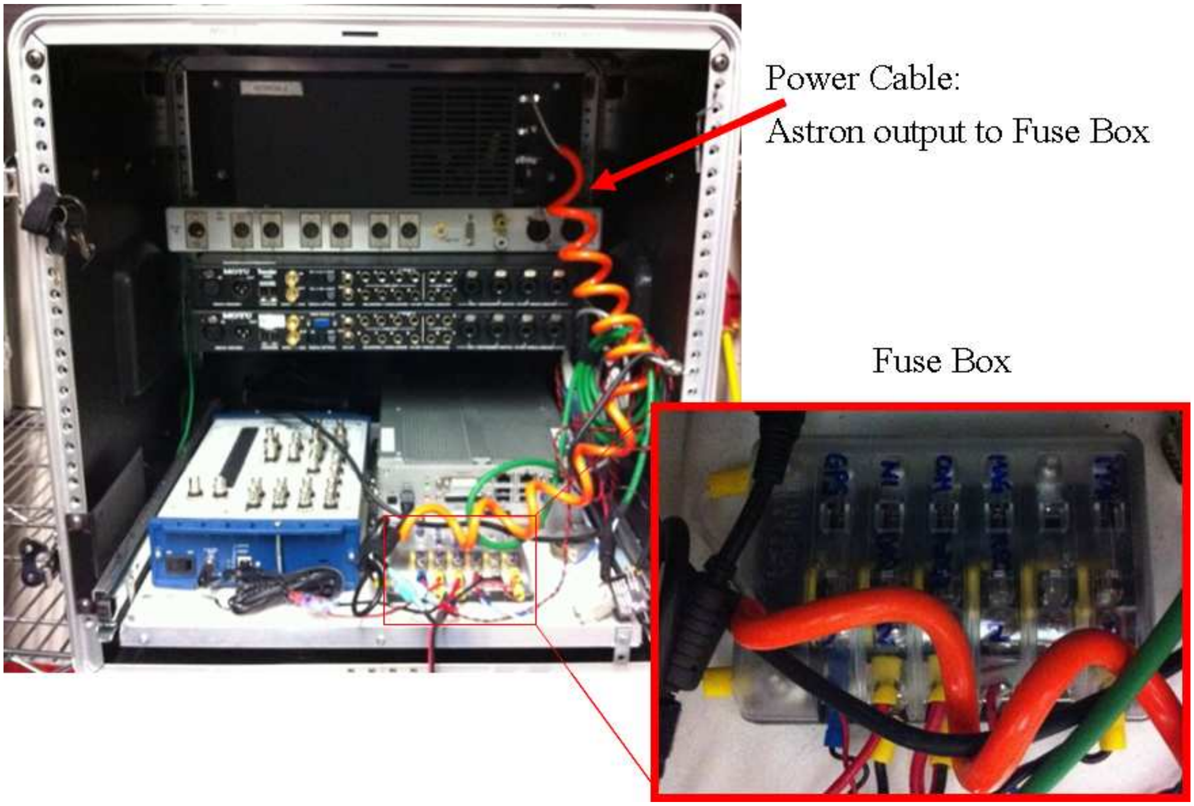

Figure 2. Anterior view of ARS showing lower level sliding tray with fuse box. The orange cable leads the 12v output power from the Astron to the fuse box, which supplies 12v power to each device along with an in-line fuse.

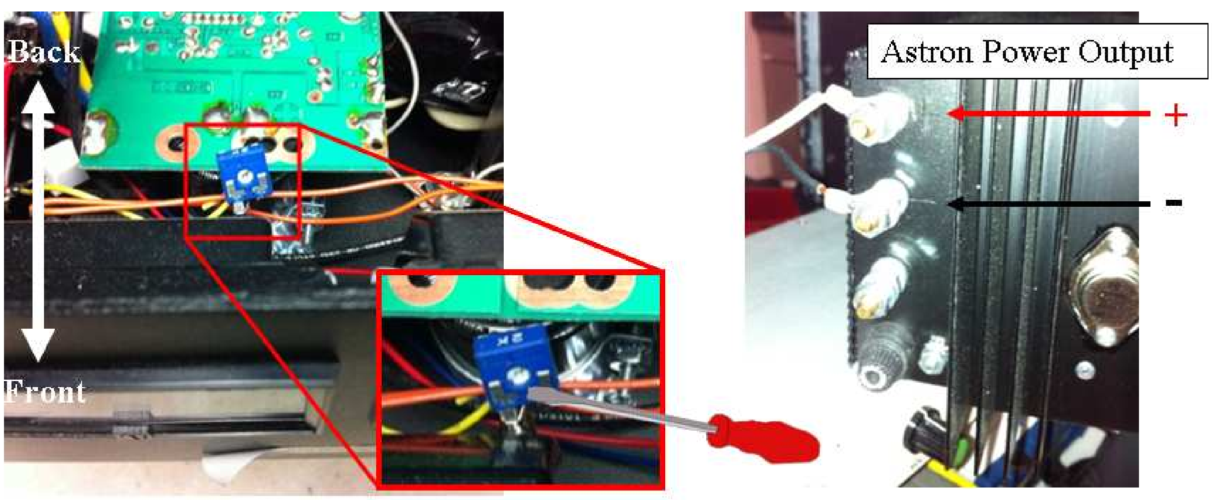

Figure 3. Modification of Astron power supply to provide 12 v power. Unplug device, remove cover, and connect voltmeter between terminals. Using a screwdriver, turn the white knob all the way counter-clockwise, then slowly turn knob clockwise until you reach 12v. It is important to not overshoot, as it takes a little time for the voltage to stabilize. If you overshoot, you may need to turn off the unit and begin again.

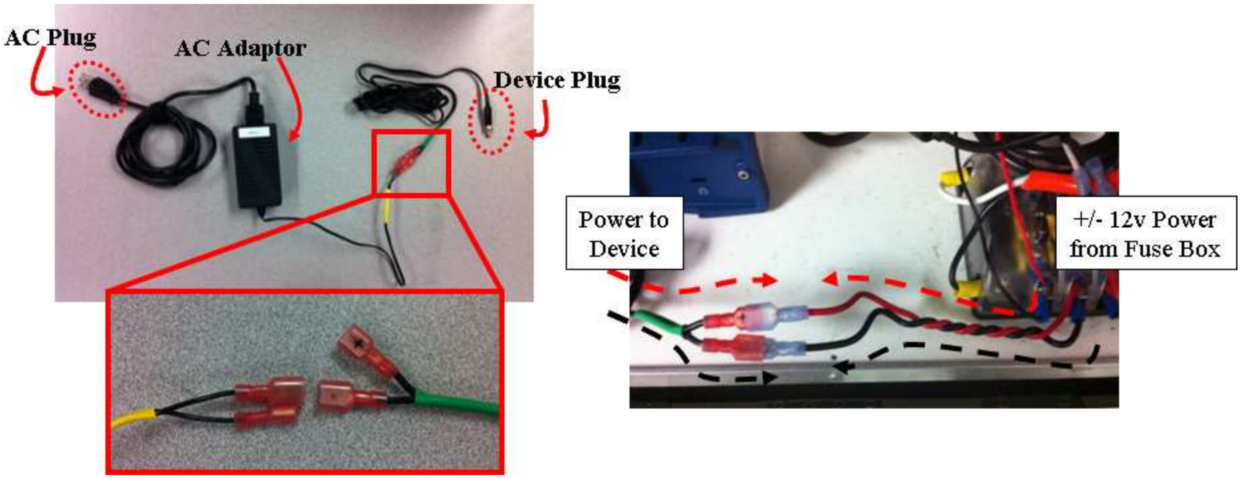

Figure 4. Modification of power cables for hardware devices. Each device should come with a power cable (device plug → AC power adaptor → AC plug). The ¼" insulated paddle connectors should be crimped/spliced in-line between the device plug and the AC adaptor. This allows the unit to be connected to 12v power via the fuse box (using the device plug → paddle), or to use AC power (device plug → paddles → AC power adaptor → AC plug). For consistency, always use the male (paddle) connector for the positive (+) supply voltage and the female (socket) connector for the negative (–) supply and label the connectors (see Fig. 5).

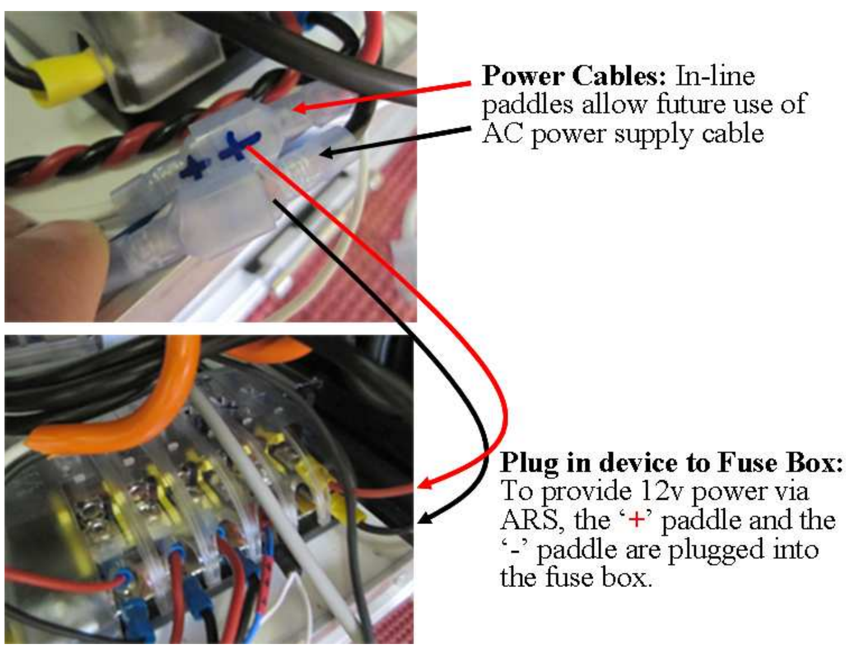

Figure 5. 12v power can be supplied to the devices by plugging the '+' and '-' paddles into the fuse box.

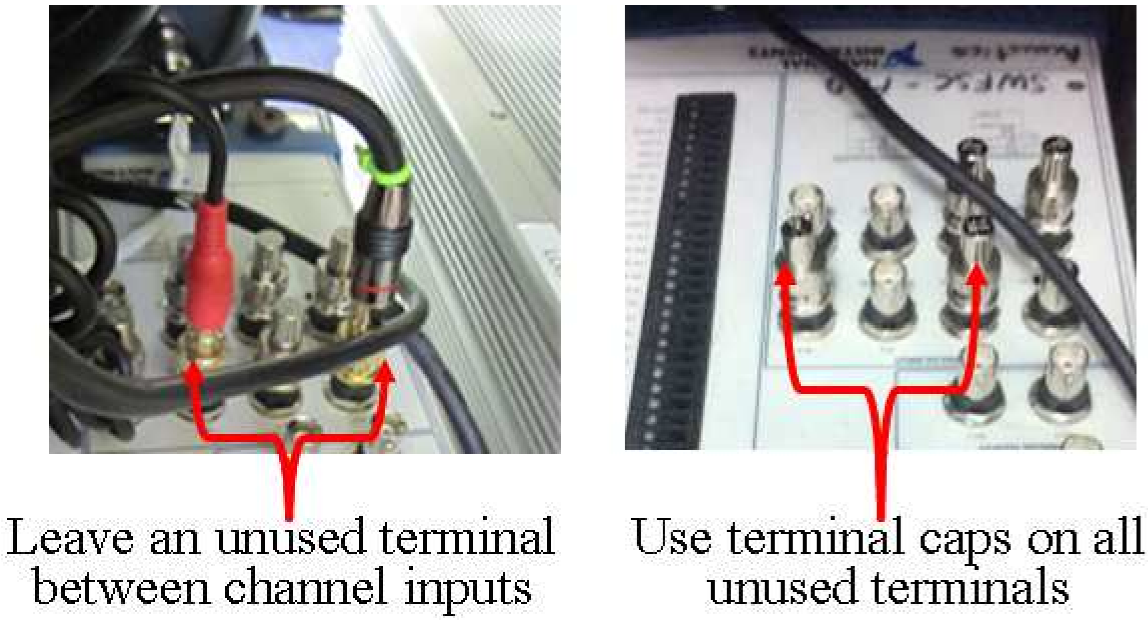

Figure 6. Suggested modifications to NI-DAQ to minimize noise. Small amounts of noise has been found to leak between terminals. We found that separating channel inputs by an unused terminal decreased noise, as well as capping unused terminals with end caps.

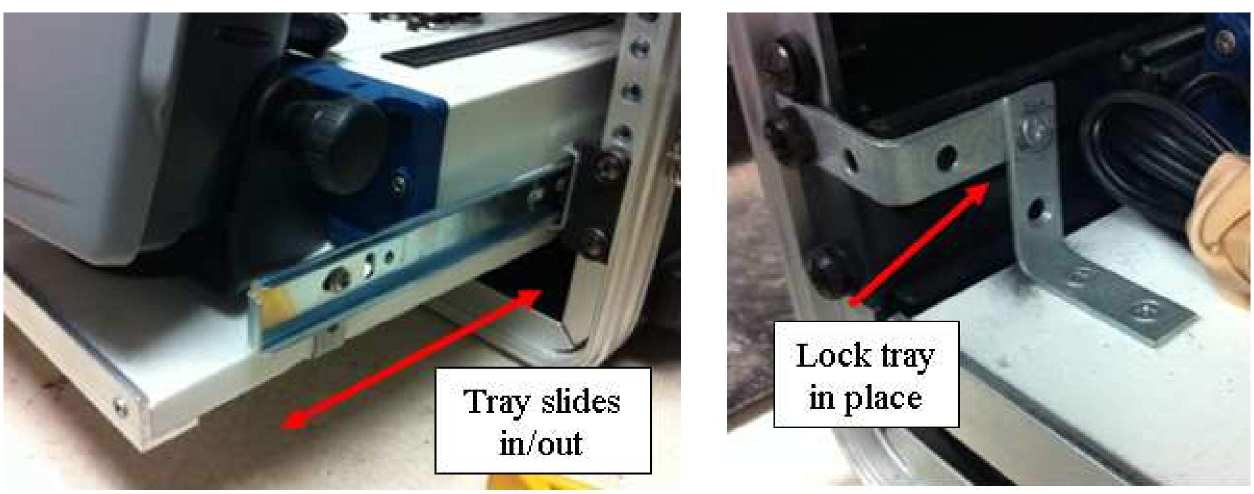

Figure 7. Tray modification to provide platform and easy access to computer, NI-DAQ, GPS, and fuse box.