

# DART

## Manual and Documentation

### **WARNING**

Read this manual in its entirety before attempting to assemble or operate the Dart instrument. Operation of the Dart equipment by untrained or unqualified personnel can expose the operator and other persons to serious injury.



Magnets in the downhole probes create a strong magnetic field that is always present, even when no power is connected. Use caution when transporting the probes. Do not allow magnetic objects near the probes; magnetic objects and probes will be attracted and may become projectiles if not secured. Persons wearing any type of electronic medical device must not operate the system and should remain at least **2 meters (6 feet) away from all instrument components** due to strong magnetic fields.



12201 Cyrus Way, Suite 104,

Mukilteo, WA, USA 98275

Tel +1 (425) 493-8122 | Fax +1 (425) 493-8223

support@vista-clara.com

[www.vista-clara.com](http://www.vista-clara.com)

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### **Limited Warranty**

Vista Clara Inc. guarantees the Dart equipment and Dart software for one year from the date of shipment when used according to our instructions, as described in the Dart Manual and Documentation. Equipment or software which proves to be defective upon inspection by Vista Clara Inc. will be replaced or repaired free of charge, including freight and insurance charges to and from the customer. No allowance will be made for customer's labor or other expenses incurred by the customer in making exchanges, replacements or repairs. No equipment will be accepted for return without a return goods authorization. Any equipment failures due to accidents, accidental or intentional misuse of the equipment, damage caused by insufficient protection during transit, faulty installation, maintenance or repairs carried out by a person other than the vendor or his agent, or from alterations carried out without the Vista Clara's consent in writing, or normal wear and tear are excluded from the warranty. The Dart equipment contains sensitive electronic instrumentation and must be handled with care at all times.

### **Limitations of Liability**

Vista Clara Inc. expressly disclaims any liability whether in negligence, strict liability, or warranty for damage or injuries resulting from using, operating, servicing, maintaining, or failure of the equipment caused by not following Vista Clara's safety warnings, manuals, and training or because of the sole negligence of purchaser.

### **Limited License**

The purchaser is granted a limited use license to use Vista Clara's technologies, including its proprietary processing and other software, for its own use only in order to operate the Dart equipment and to process data collected by the Dart equipment. Vista Clara retains ownership of the technologies. The purchaser is not authorized to make or provide copies of the software or sublicense the technologies to anyone else or to use the software for any other purpose.

### **Certification**

At end of document.

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# 1 WARNINGS AND ALERTS



The following document contains important information regarding the safe and effective operation of your new Dart system. Improper use of this system can result in physical damage to the instrument, personal injury, or even death.

It is essential that you read carefully through the entire Manual and Documentation (especially the Safety Information) before attempting to operate the system.

## 1.1 SYMBOLS USED

The symbols used in this Manual and Documentation have the following meanings.

	<b>DANGER:</b> Indicates a potentially hazardous situation which, if not avoided, will result in death or serious injury
	<b>WARNING:</b> Indicates a hazardous situation that, if not avoided, could result in a moderate injury
	<b>CAUTION:</b> Indicates a potentially hazardous situation or an unintended use which, if not avoided, may result in minor or moderate injury and/or appreciable material, financial and environmental damage
	<b>MAGNETIC FIELD HAZARD:</b> Indicates a hazard associated with strong magnetic fields
	<b>ELECTRICAL HAZARD:</b> Indicates an electrical hazard associated with high-voltage power
	<b>NOTICE:</b> Highlights important notes or instructions which must be closely followed for proper operation of equipment or software

## 1.2 SUMMARY OF WARNINGS AND ALERTS

All warnings and alerts from this document are excerpted and summarized below. This is for reference only and is not a substitute for reading this documentation in its entirety.

**1.2.1.1 DANGERS**

**⚠ DANGER**

The Downhole Cable carries high-voltage power to the probe. If the cable is damaged, discontinue use immediately.



**⚠ DANGER**

The Dart instrument generates and stores very large amounts of electrical energy. Attempting to service the Dart internal electronics can cause severe electrical shocks, burns, or even death. **With the exception of the o-ring connection on the downhole cable, the Dart contains no user-serviceable parts.** Unauthorized servicing or accessing of components internal control unit or downhole probes will render the system unsafe for use.



**1.2.1.2 WARNINGS**



**⚠ WARNING**

Persons wearing any type of electronic medical device such as a pacemaker must not operate the system and should remain at least 5 meters (15 feet) away from all instrument components due to strong magnetic fields.



**⚠ WARNING**

Magnets in the downhole probes create a strong magnetic field that is always present, even when no power is connected. Use extreme caution when transporting the probes. Do not allow magnetic objects (such as steel) near the probes; magnetic objects and probes will be attracted and may become projectiles if not properly secured. Magnetic fields can cause damage to electronics and devices with magnetic encoding (e.g., hard drives and credit cards); keep all such objects away from probes.



**⚠ WARNING**

Never connect or disconnect any cable when the system is powered on as high voltage may be present that may cause personal injury and permanent damage to the probe.



**⚠ WARNING**

The Dart Control Unit is not approved for use in the rain. In case of rain, the Control Unit must be kept covered and dry at all times. Under no circumstances should the instrument be used if there is a chance of lightning. The user's first responsibility is for the safety of all field operators; if lightning is nearby, abandon the system without regard to its current state and seek shelter immediately.



### 1.2.1.3 NOTICES

#### NOTICE

If operated with a pulley or sheave wheel, the Dart system requires a large diameter sheave wheel (at least 11 inches in diameter). The Downhole Cable will break if it is bent sharply; the minimum bending radius for the cable is 5.5 inches. Never use a pulley or sheave wheel with a diameter less than 11 inches. Using a smaller diameter sheave wheel can damage the cable irreparably.

#### NOTICE

Make sure to check all O-rings prior to every connection and after every disconnection. Replace, clean, and lubricate any O-rings if necessary. Never attempt to operate probe with missing O-rings.

#### NOTICE

DO NOT power on the Dart system until all connections are completed. Powered operation is described in the "Operation" section. Powering on the system before properly connecting all components may cause permanent damage to the Dart system

#### NOTICE

It is important that the calibration files remain unchanged and that the user can easily select the proper calibration file when prompted by software. Use of an incorrect or corrupted calibration file will lead to improper acquisition and will render data collected unusable. Carefully maintain clear file and directory naming conventions for your calibration files.

#### NOTICE

It is critical that the correct calibration folder be selected. Use of an incorrect calibration file will lead to improper acquisition and will render data collected unusable. Carefully maintain clear file and directory naming conventions for your calibration files.

#### NOTICE

If the the Ping and Logger software programs are provided as separate programs, they should not be open at the same time. Be sure to exit one window before opening another (e.g. exit the Ping software before opening the Logger software). The Launcher window will always remain open in the background.

#### NOTICE

You must specify a new folder for data acquisition that does not contain any existing Dart data files. Otherwise you will receive an error.

## 2 PRODUCT IDENTIFICATION

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Discus Dart Control Unit

Serial No. : ***DDCU-XXX***

Downhole Probe

Serial No. : ***DART-XXXX***

Reference Coil

Serial No. : ***DREF-XXX***

***(where XX = 01, 02, 03, ..., nn)***

### 3 INTRODUCTION

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Dart is a magnetic resonance logging system. The tool can be used in open or PVC-cased boreholes to estimate formation properties including porosity and permeability.

**Intended Users:** The intended user for the Dart is a trained geophysicist or hydrogeologist, familiar with downhole logging geophysics. All users must read the manual in its entirety before operating the system. The Dart is intended to be operated under direct user supervision and should not be left unattended while operating.

**Intended Use:** The intended for use measuring underground moisture and water content. Dart data will be impaired if used in environments with high levels of cultural noise so is not intended for use in direct proximity to other electrical instruments or machinery. The Dart logging cable and downhole probe are intended to be submerged in water, but the Dart Control unit is intended to be used in a dry environment, not in direct sunlight, and with adequate airflow.

**Unapproved Use:** The Dart system is not approved for use where the system is not attended by the user. The Dart Control unit is not approved for use in the rain. The Dart Control unit is not approved for use with any sensors other than those provided by Vista Clara. The Dart is not approved for use in lightning. The Dart cable has a minimum bend radius of 5.5 inches and so is not approved for uses where the cable would be bent sharply.

### **3.1 INCLUDED IN THE DART SYSTEM**

#### **Primary Instrument Units**

Dart Control Unit

Dart Downhole Probe

#### **Additional Components**

Downhole Logging Cable

Connection Cables

Field Laptop Computer

Noise Reference Coil (some units)

Internal Batteries (some units)

#### **Software**

Dart NMR Logger Acquisition Software

NMR Processing Software

NMR Interpretation Software

#### **Documentation**

Dart Manual and Documentation (this document)

## 4 COMPONENTS

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### 4.1 UNPACKING THE SYSTEM



Magnets in the downhole probes create strong magnetic fields that are always present, even when no power is connected. Use extreme caution when transporting the probes. Do not allow magnetic objects (such as steel) near the probes; magnetic objects and probes will be attracted and may become projectiles if not properly secured. Magnetic fields can cause damage to electronics and devices with magnetic encoding (e.g., hard drives and credit cards); keep all such objects away from probes.

The Dart system is delivered in shipping cases which should be retained for future shipping needs. The downhole probe is encased in a steel magnetic shielding tube inside the plastic cases and should always be placed in the shielding tube for shipping. Before unpacking the probes, ensure that there are no unsecured magnetic objects or electronics nearby in the unpacking area.

After unpacking the system, the purchaser should check all system components for signs of damage during shipping. If any dents, scrapes, or rattling noises are observed, the purchaser should not use the system and should immediately contact Vista Clara, Inc. to discuss repairs.

### 4.2 COMPONENT SPECIFICATIONS AND ASSEMBLY

The Dart system has three primary units: Control Unit, Downhole Probe, and Downhole Cable. Additional components include the connection cables, optional Reference Coil, and optional internal batteries. The specifications, electrical requirements, and important safety features of each component are outlined in the following “Component Specifications and Assembly” section. At the end of this section, instructions for assembling the system are outlined.

### 4.3 DART CONTROL UNIT

The Dart Control Unit controls and powers the downhole probe. The Control Unit is powered from a battery supply that may be internal batteries or an external battery. The Control Unit provides high-voltage power to the probe via the Downhole Cable connected to the “SENSOR” output. The Control Unit also interfaces with the field computer through the USB data cable.



Figure 1: Dart Control Unit (12V spec version).

#### **⚠ DANGER**

The Control Unit produces high-voltage power. Never touch, connect, or disconnect the Downhole Cable or Dart Adapter Cable when the system is powered on.



#### **Specifications:**

#### **Electrical Requirements:**

<p>Weight: approximately 30 lb.                  Dimensions: 18L X 12 W X 10 H in.                  Standby power consumption: 20 W                  Peak power consumption: 2000 W                  USB Communications</p>	<p>DC Battery: 12-16V (some units)                  DC Battery: 24V (some units)</p>
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### 4.4 DOWNHOLE PROBE

The Downhole Probe collects NMR measurements of fluids in a Earth formation when lowered into a PVC-cased or open borehole. Permanent magnets in the probe project a static magnetic field into the formation. NMR signals are measured from within a thin cylindrical shell surrounding the probe using pulsed oscillating magnetic fields.

**WARNING**

Magnets in the downhole probes create strong magnetic fields that are present even when no power is connected. Use caution when transporting the probes. Do not allow magnetic objects (such as steel) near the probes; magnetic objects and probes will be attracted and may become projectiles if not secured.



Persons wearing any type of electronic medical device such as a pacemaker must not operate the system and should remain at least 5 meters (15 feet) away from all instrument components due to strong magnetic fields.



Figure 2: Dart Probe.

Specifications:	Electrical Requirements:
Weight: 14 lb. Diameter: 1.75 inches Length: 68 inches	Power supplied by Control Unit via Downhole Cable

### 4.5 DOWNHOLE CABLE

The Downhole Cable is used to raise and lower the Downhole Probe. The cable interfaces with the Control Unit via the “SENSOR” port. For some systems, an adapter cable is required to connect the Downhole Cable and the Sensor Port.

**⚠ DANGER** The Downhole Cable carries high-voltage power to the probe. If the cable is damaged, discontinue use immediately.

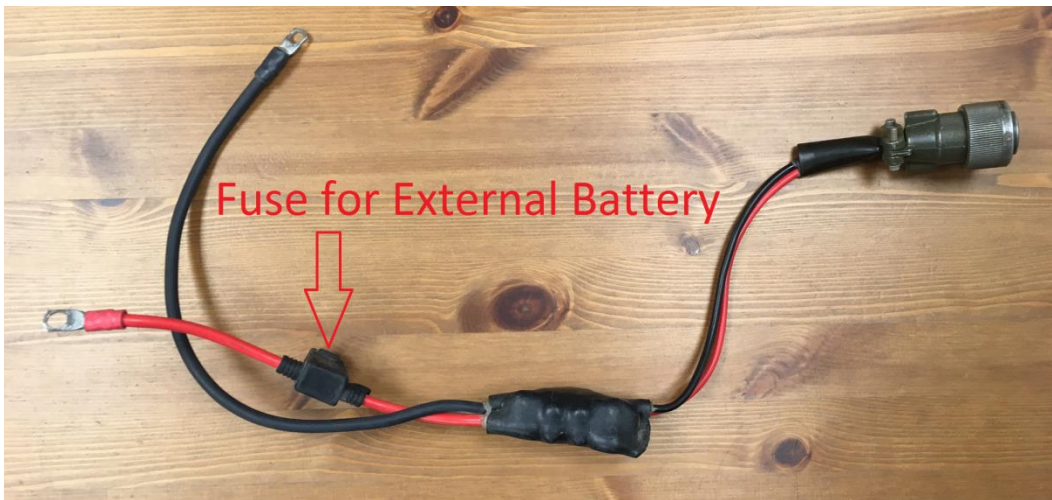


**NOTICE** The internal leads in the Downhole Cable will break if the cable is bent sharply. The minimum bending radius for the cable is 5.5 inches. **Never kink the cable or use a pulley wheel with a diameter of less than 11 inches.**

## 4.6 ADDITIONAL COMPONENTS

### External Battery Cable

The External Battery cable provides connection between external 12V batteries and the Battery Port on the Control Unit panel.



*Figure 3: Cable for connecting a Dart Control Unit to external batteries.*

Fuse Ordering information: Littlefuse Inc. P/N: 0895020.U (Digikey P/N: F4344-NDFUSE AUTO 20A 58VDC 500 PC.)



### Optional Reference Coil

The optional reference coil box is used to cancel environmental noise encountered in very shallow investigations. The coil box is connected to the Control Unit via a custom keyed cable.



*Figure 4: (Optional) Reference coil and cable.*

### Optional Tripod and Sheave Wheel

#### NOTICE

The Dart system requires a large diameter sheave wheel (at least 11 inches in diameter). Using a smaller diameter sheave wheel can cause irreparable damage to the cable.

## 4.7 SOFTWARE

### 4.7.1 General Software

The Basic Dart Instrument includes the following software programs:

1. **“Dart Logger”** for acquiring Dart NMR logging data.
2. **“Javelin Pro Plus”** for processing and interpreting raw Dart logging data.

The Dart software is provided on a USB thumb drive delivered with the system, or as a download sent by Vista Clara. All software should be installed before attempting to operate the Dart instrument.

### 4.7.2 Calibration Files

Calibration files provided with the Dart system contain important acquisition and processing parameters specific to the Dart model and downhole logging cable. A separate calibration folder is provided for each pairing of Dart probe and downhole

cable. These files should be carefully managed and protected to prevent changes to the file data or loss of the files. The user will be prompted by acquisition software to locate an appropriate calibration folder at the start of each logging survey.

## NOTICE

It is important that the calibration files remain unchanged and that the user can easily select the proper calibration file when prompted by software. Use of an incorrect or corrupted calibration file will lead to improper acquisition and will render data collected unusable. Carefully maintain clear file and directory naming conventions for your calibration files.

## 5 CONNECTION GUIDE

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Before attempting to connect the Dart System, read this section “Connection Guide” in its entirety. The following instructions describe how to properly and safely connect all the components of the Dart system **without power**:

## NOTICE

Never attempt to connect or disconnect any cable in the Dart system when the system is powered on. Permanent damage to the Dart System may occur if the system is powered on prior to completing connections or if any connections are adjusted while the system is powered.

## NOTICE

DO NOT power on the Dart system until all connections are completed. Powered operation is described in the "Operation" section.

### 1. Connect the Downhole Cable to the Downhole Probe

a) **Unscrew and remove the protection cap from the logging head of the Downhole Probe.**



Figure 5: Dart probe with cap in place (top) and with cap removed (bottom). Cap is shown on right.

**b) Unscrew the protection cap from the end of the Downhole Logging Cable. Check O-ring in Cable Head.** O-ring should be present, well lubricated with silicone (non-conductive) grease, and free of any dirt. If the O-ring is dirty or not well lubricated, follow the instructions for cleaning and lubricating the O-ring in "System Care".

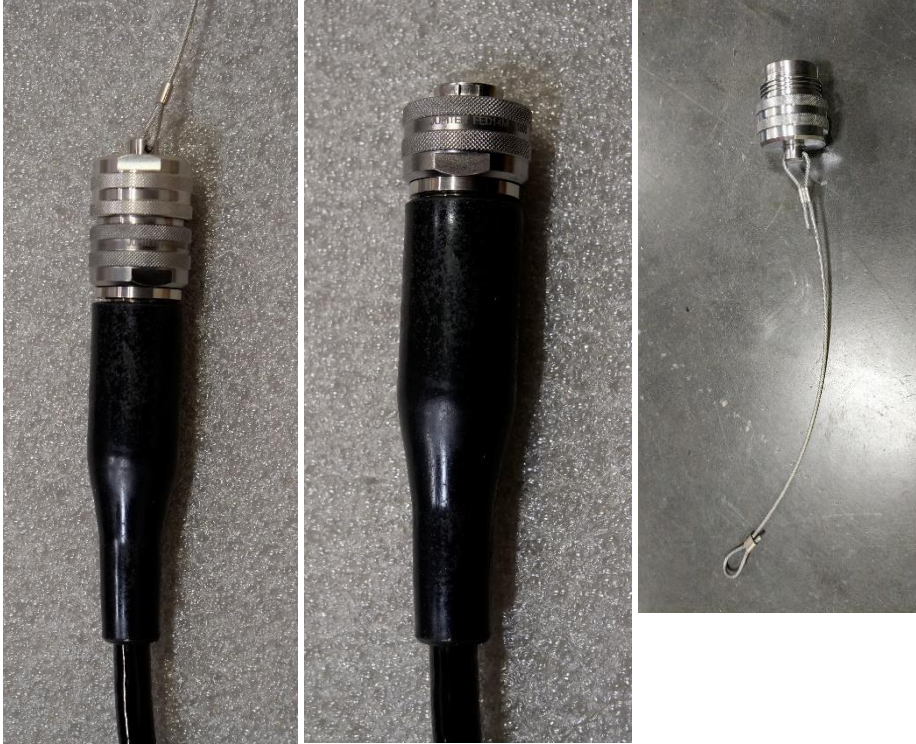


Figure 6: Cable head with cap in place (left), with cap removed (middle), and cap (right).

**c) Store both caps during logging by screwing them together and placing in a secure location.**

Connecting the caps keeps the threads in interiors clean and free of dirt.



Figure 7: Caps stored in a connected state during logging.

**c) Connect the Downhole Cable to the Downhole Probe Logging Head**

Alignment 'keys' in the connection joint ensure that the connection can only be made in a single, unique orientation. Do not attempt to make the connection between cable head and probe in any orientation other than that dictated by the alignment keys.



As you insert the Downhole Cable end connector into the logging head connector, twist the connections so that the keys align; you will feel the connections dock and may hear a subtle click. Ensure the connection keys are aligned before tightening the retention ring. Gently tighten the screw ring; hand tightening is sufficient; do not use tools to tighten.

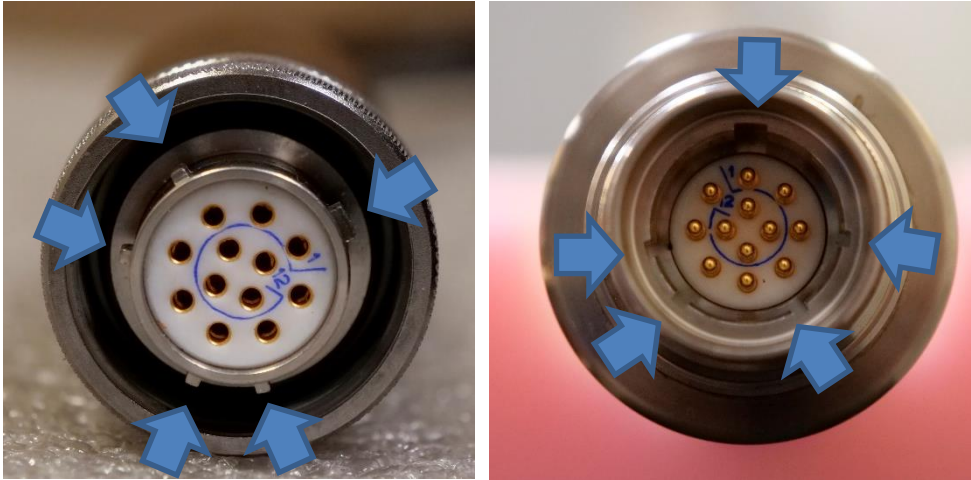


Figure 8: View inside the logging cable (left) and Dart probe (right). Alignment 'keys' are indicated by arrows.



Figure 9: Logging cable attached to Dart probe.

## 2. Connect Downhole Cable to "SENSOR" Port on the Control Unit

Align the key on the Downhole Cable or adapter cable and insert into the Sensor Port. Rotate the barrel of the Adapter Cable until you feel it click into an engaged position. Do not tighten past the click.

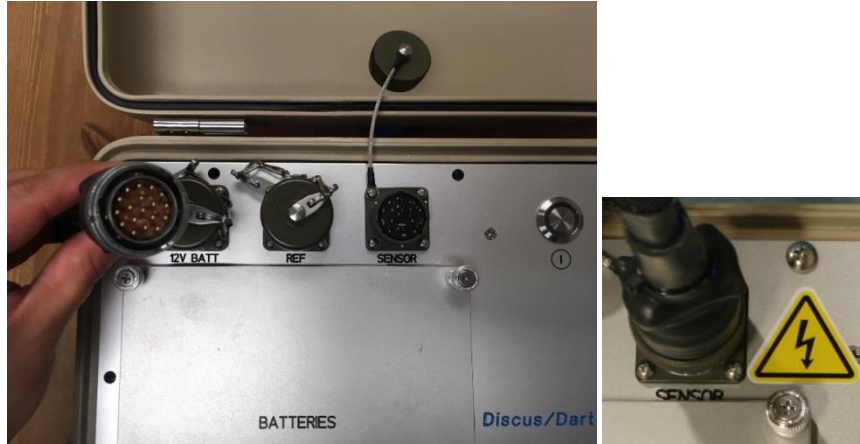


Figure 10: Connection between Dart Adapter Cable and Dart Control Unit.

### 3. Connect Field Computer via the USB Port

Insert the Data Cable into the USB connection on the Dart Control Unit. Align the connectors and turn the barrel of the USB Cable connector until you feel it click into an engaged position. Connect the other side of the USB Cable to the laptop computer.

### 4. Connect Reference Coil to Control Unit (option)

a) Insert the female end of the Reference Cable into the port on the Reference Coil box and hand tighten the threaded connection.

b) Insert the male end of the Reference Cable into the "REF" port on the Control Unit and hand tighten the threaded connection.

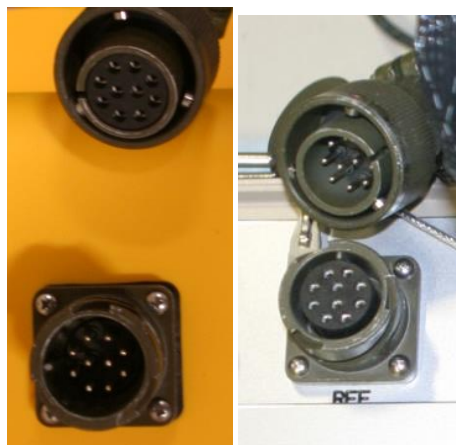


Figure 11: Reference Channel Cable connection to Reference Coil box (left) and Control Unit (right).

### 5. Connect battery power

The Dart system can be powered from internal 12V batteries or an external battery supply. The external supply voltage requirement may be 12V or 24V depending on the

design of your Control Unit. The voltage required will be indicated on the top panel of the Control Unit. (Current spec Dart units require a 24V external battery source.)

**Connecting internal battery supply:**

- a) Loosen the retaining nuts on the battery compartment lid on the front panel of the Control Unit. Remove lid.
- b) Place two internal batteries upright inside the Dart Control unit.
- c) Connect the keyed internal battery connectors to the two internal batteries.

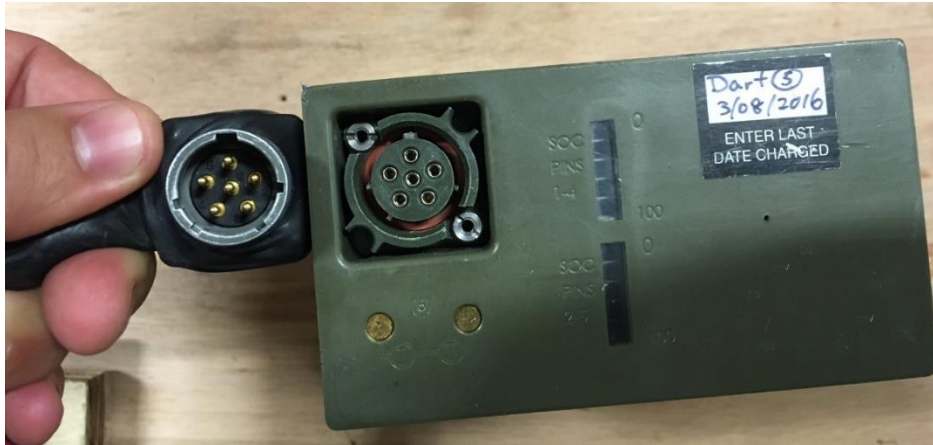


Figure 12: Connection Between Internal Battery Cable and Internal Battery.



**Fuse Ordering information: Littlefuse Inc. P/N: 0895020.U (Digikey P/N: F4344-NDFUSE AUTO 20A 58VDC 500 PC.)**

**Connecting external battery supply (24V-spec units):**

- a) Use two fully charged 12V Deep Cycle batteries.
- b) Connect the red lead of the External Battery Cable to the positive (+) terminal of the first 12V battery and fasten using a wingnut.
- c) Connect the black lead of the External Battery Cable to the negative (-) terminal of the second 12V battery and fasten using a wingnut.
- d) Connect a jumper between the negative (-) terminal of the first 12V battery and the positive terminal of the second 12V battery and fasten with wing nuts.
- e) Connect the bayonet connector of the External Battery Cable to the 24V Battery Port on the Control Unit panel and fasten until the connector clicks into place.



*Figure 13: Connection of external 12V batteries in 24V supply configuration.*



*Figure 14: Connection from External Battery Cable to Control Unit "24V BATT" Port.*

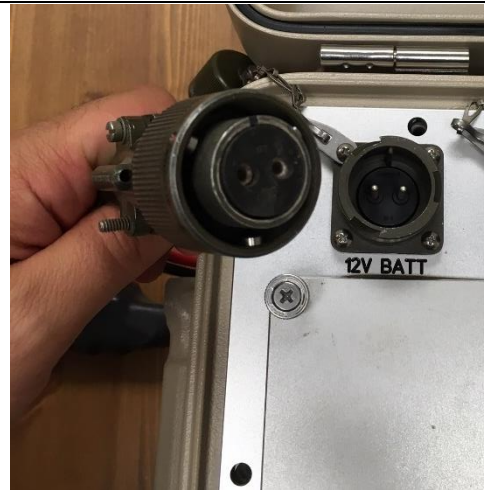


**Connecting external battery supply (12V-spec units):**

- a) Use one fully charged 12V Deep Cycle battery.
- b) Connect the red lead of the External Battery Cable to the positive (+) terminal of the battery and fasten using a wingnut.
- c) Connect the black lead of the External Battery Cable to the negative (-) terminal of the battery and fasten using a wingnut.
- d) Connect the bayonet connector of the External Battery Cable to the 12V Battery Port on the Control Unit panel and fasten until the connector clicks into place.



*Figure 15: Connection Between External Battery Cable and External Battery.*



*Figure 16: Connection from External Battery Cable to Control Unit "12V BATT" Port.*

## 6 DISCONNECTION GUIDE

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The following instructions describe how to properly and safely shut down and disconnect all components of the Dart system:

**⚠ WARNING** Never connect or disconnect any cable when the system is powered on as high voltage may be present that may cause personal injury and permanent damage to the probe.



### 1. Turn off the Control Unit

Turn off the Control Unit by pressing the main power switch. You will see the green power light turn off.



*Figure 17: Main Power Button on Dart Control Unit.*

### 2. Disconnect the Batteries

### 3. Power down and store the Field Computer

Power down the Field computer and store it in a safe place.

### 4. Remove and Disconnect the Downhole Probe

**⚠ WARNING** Magnets in the downhole probes create strong magnetic fields. Use caution when handling and transporting the probes.



a) Remove the Downhole Probe from the logging hole and place probe on the ground. Do not attempt to remove the Cable from the Probe while the Probe is hanging or above the wellhead.

b) Disconnect the Downhole Cable from the Probe logging head by unscrewing the retention ring at the base of the cable. **Twist only the retention ring. Do not attempt to unscrew the logging head assembly from the probe.**



c) Replace protective caps on probe and cable head.



Figure 18: Protective caps in place on cable head (left) and probe (right).

d) Store the probes in the steel tubes and cases for safe transport.

**NOTICE**

Check that all O-rings are in place following disconnection. An O-ring should be located in the Cable Logging Head and Dart probe cap.

**5. Disconnect remaining cables and pack components**

Disconnect all remaining cables and store them in the cable case. Replace caps on all connection ports and close the Control Unit casing.

## 7 OPERATION

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### 7.1 OPERATOR QUALIFICATIONS

The Dart system is intended for operation by a geophysicist, engineer, or hydrologist who is familiar with geophysical logging measurements. All operators must read the manual in its entirety before operating the system. The system must not be operated by any untrained persons.

### 7.2 WEATHER PLANNING

**⚠ WARNING** The Dart Control Unit is not approved for use in the rain! In case of rain, the Control Unit must be kept covered and dry at all times. Under no circumstances should the instrument be used if there is a chance of lightning.

The user is responsible for monitoring changing weather conditions and responding appropriately before a danger becomes present. If weather changes and a storm becomes likely, seek shelter. The following preventative steps for protecting the Javlin system should be carried out only if conditions safely permit with the following priority:

- (i) Turn off the system.
- (ii) Disconnect cables and replace unit covers.

The user's first responsibility is for the safety of all field operators.

If lightning is nearby, abandon the system without regard to its current state and seek shelter immediately!

### 7.3 SURVEY SETUP

**⚠ WARNING** WAIT: Do not power on the system until instructed to do so in the following section "Running the Dart System". Powering on the system before properly connecting all components may cause permanent damage to the Dart system.

#### 1. Determine Survey Geometry

Prior to setting up a logging survey, determine a working geometry for the survey. Components and cable should be arranged in a manner that minimizes hazards. Ensure that the logging cable will not be disturbed by persons or vehicles.

#### 2. Connect all components

Connect all components following the instructions in the section "Connection Guide."

#### **NOTICE**

Make sure to check all O-rings prior to connection. Replace, clean, and lubricate any O-rings if necessary. Never attempt to operate probe with missing O-rings.

#### 3. Set the downhole probe at the desired initial depth

Determine the desired starting depth and set the probe to the proper vertical

location. It is good practice to reference all measurement depths based on the distance from the top of the well head to the top of the logging head (the end of the logging cable). This distance can be easily monitored by using the depth encoder (if available) or by observing the depth demarkations on the downhole cable and noting which demarkation is inline with the top of the well head. Keep in mind that there is a vertical offset between the logging head and the sensitive zone of each downhole probe; this distance differs between the various downhole probes. This vertical offset from the logging head is corrected in the processing software.

## 7.4 DIRECT PUSH [OPTIONAL]

The Dart probe model 'DP140N' is designed for deployment via Direct Push using 2.25in GeoProbe rods. This section provides an overview of the method for collecting data in this scenario.

### 7.4.1 Required Equipment

Direct Push deployment requires additional tooling compared to a standard Dart log. Some of this tooling is provided by Vista Clara, and some must be sourced by the end-user. Ensure that you fully understand the tooling requirements and have sources for all necessary components prior to mobilization.

Refer to Section 12.7 "Parts and Accessories Required for Direct Push Deployment" for a complete description of this required tooling.

The condition of the 2.25in drill rods is critical to successful deployment. Rods should be clean and undeformed. Use of new rods is recommended. Rods which are damaged, deformed, or caked on the interior can prevent passage of the Dart probe, requiring the boring to be abandoned or re-drilled. Inspect all rods prior to use. The upper end of the Dart probe can be test-fit through each rod end prior to use to ensure it passes freely. However, in some cases, rods which pass this test individually at the surface may nevertheless create uneven joints when deployed in the ground which prevent passage of the Dart probe.

### 7.4.2 Overview of the Direct Push Process

The stages of a Direct Push Dart log are:

1. Prepare GeoProbe rods.
  - a. Attach the Dart-specific drive shoe to the bottom of the 2.25in GeoProbe rod string (P/N 239182 in Table 2, see page 59).
  - b. Install an expendable point in the drive shoe.
2. Drive the rod string.
  - a. Using a GeoProbe drill rig and certified operator, drive the rod string. The Dart probe is *not* installed in the rod string during drilling.
3. Deploy the Dart probe to the bottom of the rod string.

- a. Install the cable clamp assembly (P/N 238997 in Table 2) to the cable head on the logging cable.
- b. Thread the left-hand threaded adapter (P/N 238268 in Table 2) into the cable clamp assembly.
- c. Attach the logging cable to the Dart probe. The Dart Control Unit should be powered off during the deployment of the probe through the rod string.
- d. Insert the Dart probe into the rod string. Take care to avoid having the magnetic portion of the probe attracted to the metal of the drill rig. Push the Dart probe into the rod string until only the upper 20-30cm of the probe remains above the rod string.
- e. Link one extension rod (each assembled extension rod consists of P/Ns 201352, 213839, 213838 in Table 3) to the left-hand threaded adapter and push the probe into the drill string by the length of the extension rod. Continue attaching extension rods and pushing the probe to the bottom of the rod string.
- f. *CAUTION: If the probe stops on a joint or obstruction prior to reaching the bottom of the rod string, do not pull up on the extension rod string. Pulling up on the extension rod string can damage the logging cable. Pull up only on the logging cable and use the extension rod string only for pushing. By pulling the probe up by several inches and re-advancing, you may be able to pass an obstruction. If the probe will not pass the obstruction, using the GeoProbe rig to pull up slightly on the drill rod string to put the drill rods in tension may allow the probe to pass. (Avoid pulling up on the drill rod string so much that the expendable point is lost.) If the probe will still not pass the obstruction, the log will have to be abandoned. Pull the probe out of the rod string using the logging cable, disassembling the push rod string as the probe ascends. Use the GeoProbe drill rig to withdraw the 2.25in rod string. By tracking the number of extension rods used, it is possible to identify the depth of the obstruction and remove the GeoProbe rods involved in the blockage from service. If desired, another logging attempt can be made by re-drilling the GeoProbe rod string in the same hole or an adjacent location.*
- g. Count the number of extension rods used. When the length of the extension rod string plus the length of the Dart probe equals the length of drill rods used, the Dart probe should come to rest firmly on the top side of the expendable point.
- h. One operator should hold the extension rod string in place while the GeoProbe rig operator pulls up the rod string. The extension rod string should remain at a fixed height (relative to the ground) while the drill rod string lifts. Continue lifting the drill rods a height of approximately 5ft (the height of the Dart probe) until the extension rod string starts to

lift along with the drill rod string. This indicates that the top of the Dart probe is engaged with the drive shoe.

- i. Remove the extension rod string.
  - i. Rotating the entire string clockwise until the left-hand threaded adapter has disengaged from the cable clamp assembly.
  - ii. Lift the extension rod string, removing each extension rod.
- j. Establish the starting depth of the log (see Section 7.5 “Depth Tracking Conventions”).
- k. Power on the Dart Control unit. If a depth counter is being used, set up the necessary hardware and software. Begin data collection using Stepped mode (see Section 7.6 “Running the Dart System”).
- l. At the end of the first measurement, instruct the GeoProbe operator to lift the drill rod string by the intended sampling interval<sup>1</sup> for the survey (typically 6in, 9in, or 12in). Start the next measurement. The rod string should be held stationary for each measurement.

## 7.5 DEPTH TRACKING CONVENTIONS

Various conventions are possible for tracking depth. Users must ensure that the chosen method is completely and consistently implemented to obtain correct depths during logging.

### 7.5.1 Logging in cased wells or open borings

Two conventions (see Figure 19) can be used for conducting Dart measurements in cased wells or augured borings. Tape or paint markings should be applied to the probe and logging cable using the preferred convention.

Convention A: Tracking with respect to probe center.

- The depth of each measurement indicates the distance between the center of the measurement coil and the chosen ground reference.
- The value of `probe_center_m` in the `tool.ini` calibration file must be set to 0.
- No modification to the recorded depths will be applied in the processing software.

Convention B: Tracking with respect to top of tool.

- The depth of each measurement indicates the distance between the top of the probe (at the base of the logging cable connector) and the chosen ground reference.

---

<sup>1</sup> If no depth encoder is used, it is critical that the rig operators are precise in their lift intervals. If the rods are lifted by amounts differing from the specified interval, depth errors will be introduced into the log. It can be helpful to use a sampling interval that is an even divisor of the drill rod length to help identify whether depth errors are accumulating.

- The value of `probe_center_m` in the `tool.ini` calibration file must be set to the distance between the top of the probe and the center of the measurement coil. This specification is provided by Vista Clara.
- The value of `probe_center_m` will be automatically added to all logged depths during import into the Processor software, resulting in a depth log that shows the location of the center of the measurement coil with respect to the chosen ground reference.

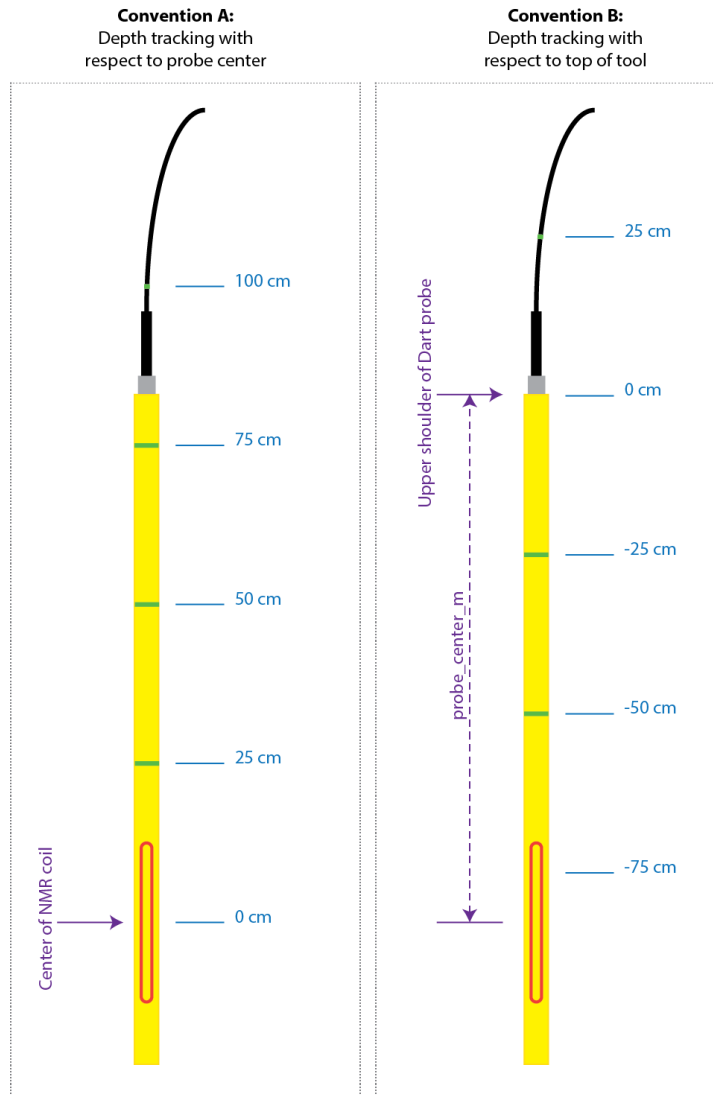


Figure 19: Two conventions for tracking depth. In Convention A, the depth of the center of the NMR measurement coil is tracked, and no offset is applied during processing. In Convention B, the depth of the top of the NMR probe is tracked, and the offset distance is applied during processing. Illustration is not to scale.

### 7.5.2 Direct Push without depth encoder

The recommended procedure for manually tracking depth during Direct Push logging is as follows:



- **Probe offset:** The value of `probe_center_m` in the `tool.ini` calibration file must be set before opening the Logger software and starting the log. This value should be distance (specified in meters) between the center of the measurement coil of the probe and the upper shoulder of the NMR drive shoe (at the base of the connection threads) while the probe is suspended in the drive shoe.
- **Depth reference during logging:** The depth reference during logging should be the bottom of the rod string below ground surface, excluding the drive shoe and expendable point. The starting depth, and the recorded depth at each logging step, will be this depth. To obtain this depth, keep a count of the number of rods used, multiply by the length of each rod, and subtract the height of the uppermost rod above ground surface. If applicable, add the height of any short rod segments added to the string.
  - Example 1: If you are preparing to start a log and you have driven in six rods, each 5ft long, and the final rod has 2ft sticking above ground surface (do not count the height of the threaded section), then the starting depth for the log will be:  $6 \text{ rods} * 5 \text{ ft/rod} - 2 \text{ ft stickup} = 28$  feet. Enter 28.0 feet in the Logger software for the starting depth of the log.
  - Example 2: If you are logging using 5ft rods and at the completion of a measurement, the Logger software indicates that you should move the probe to a depth of 11.0 ft, then you should lift the tool string and have three rods in the ground with 4 ft of the uppermost rod sticking above ground surface when you start the measurement:  $3 \text{ rods} * 5\text{ft/rod} - 4 \text{ ft stickup} = 11$  feet.
- **Stickup Height:** Do not enter any value in the text entry box for Stickup Height in the Logger software at the start of the log.
- **Implementation:**
  - The depth tracked during logging, displayed in the Logger, and written to the data files is the depth of the bottom edge of the lowermost drill rod below ground surface.
  - The static offset distance between the above location and the center of the measurement zone of the probe (which is specified by the `probe_center_m` value in the calibration files) is automatically added to the logged depth during data import into the Processor. Therefore, the depths displayed in the Processor will be the depth of the NMR measurement below ground surface.

### 7.5.3 Direct Push with depth encoder

Consult with Vista Clara and/or GeoProbe for the most current directions on use of depth tracking hardware.

## 7.6 RUNNING THE DART SYSTEM

### 1. Check connection of all hardware components but DO NOT power on the Control Unit

Do not power on the system. Ensure that all components are properly connected as described in Section “Connection Guide” and check that all connections are hand-tight.

### 2. Power on the Field Computer

If you have not already done so, power on the field computer and connect the USB cable to the Dart Control Unit. Do not open any software at this time.

### 3. Power on the Dart Control Unit

Once all hardware components are plugged in, power on the Control Unit by pressing the power switch. You will see the main power light illuminate.

### 4. Open the Dart Logging Software

Refer to Section 7.6.1.

#### 7.6.1 Dart Logger software

Upon opening the software, you will be prompted to select a calibration folder. By default, the logger will search for calibrations in C:\VC\_NMR\_DATA\Calibrations\. Navigate to and select the correct calibration folder<sup>2</sup>. Within the calibration folder there may be several calibrations for various echo spacings (see Figure 21). Select the echo spacing you wish to use by double-clicking and opening the corresponding folder.

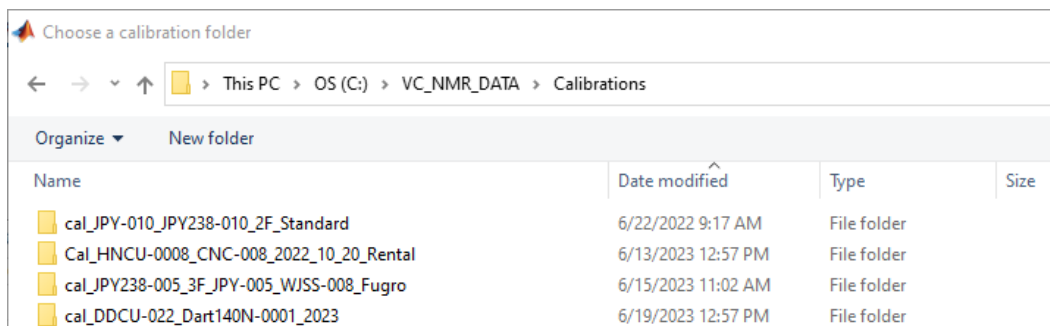


Figure 20: File explorer showing default calibration directory with several example calibrations shown.

<sup>2</sup> For more information on Calibration Files, refer to Section 4.7.2, Calibration (Page 16).

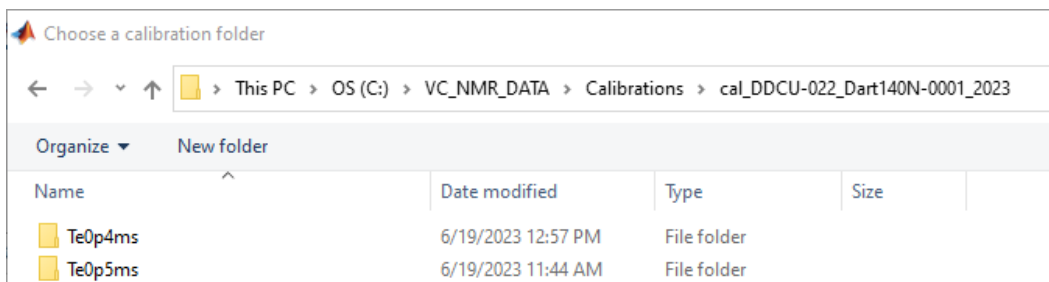


Figure 21: File explorer showing calibrations at different echo spacings. “Te0p4ms” indicates an echo spacing of 0.4ms and “Te0p5ms” indicates an echo spacing of 0.5ms.

After clicking into the calibration folder, press “Select Folder” in the file explorer. Note that the files in this folder will be hidden in the folder selection dialog.

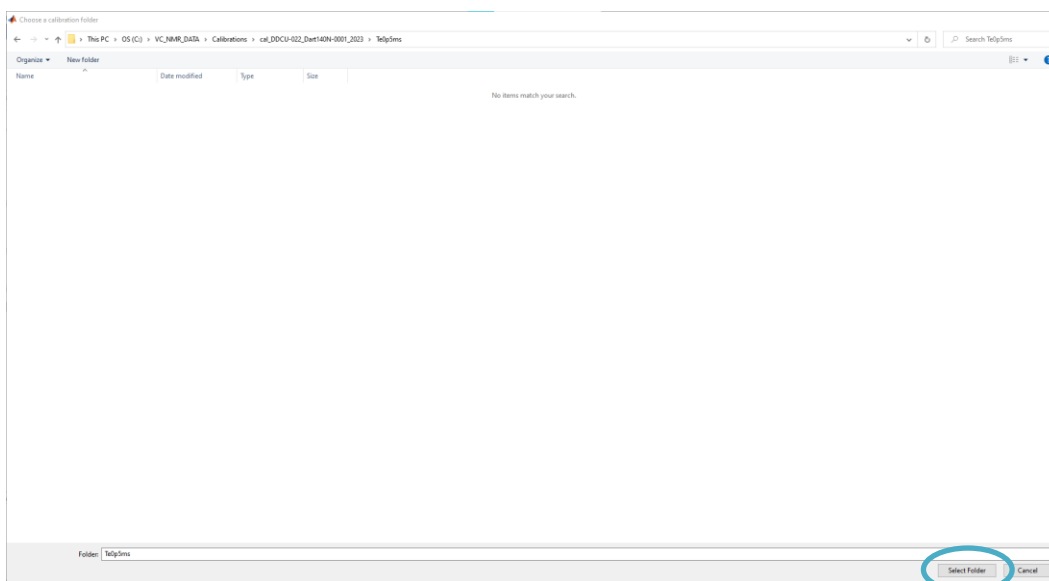


Figure 22: Click ‘Select Folder’ when the file browser is in the desired calibration folder. The calibration files will be hidden in this view..

After selecting the calibration folder, the main NMR Logger window will open as shown in Figure 23.

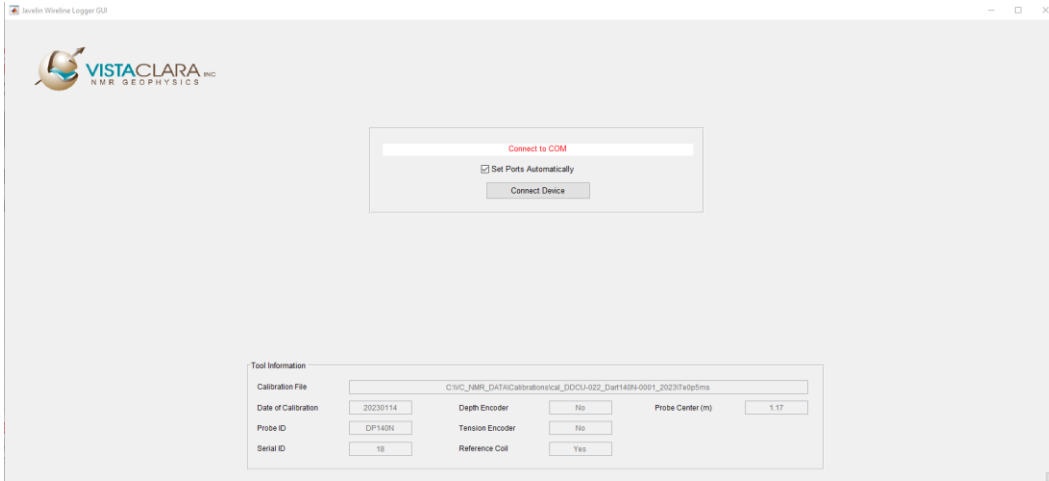


Figure 23: Dart Logger data acquisition software on start-up.

This initial screen will display relevant information read from the calibration file, such as the date of calibration, probe ID, the length to the probe center, and whether the calibration file enables reading from a depth encoder, tension encoder, and reference coil.

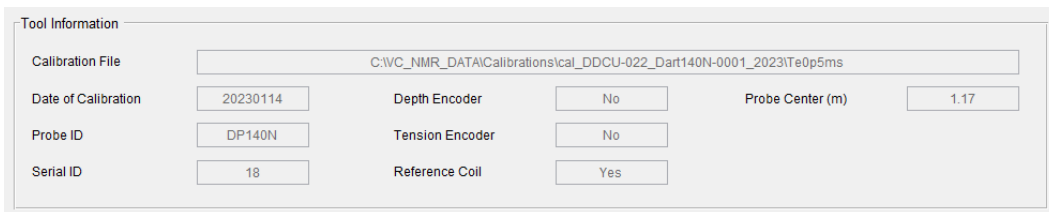
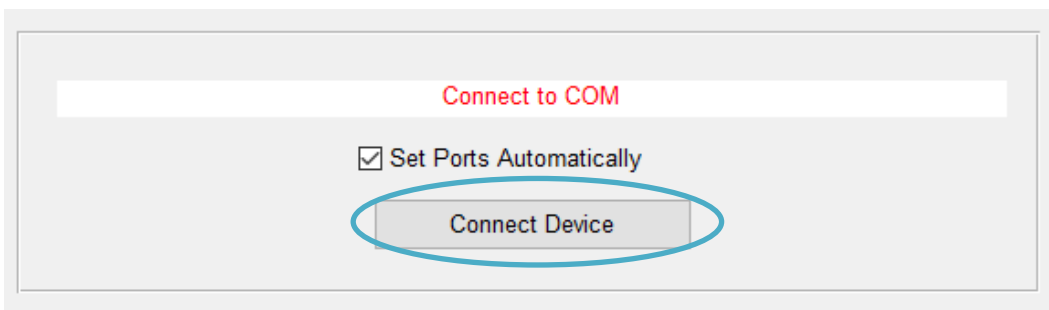


Figure 24: Dart Logger tool information panel.

On this screen the user will also be prompted to connect to the devices. By default, the logger is set to search the ports automatically after clicking “Connect Device”. It will search for the NMR tool over USB connection. If running with an integrated depth encoder, the autodetect function will also search for that serial port as well.



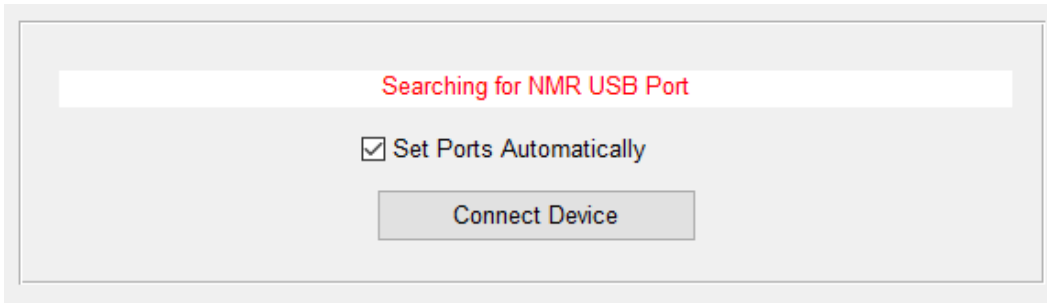


Figure 25: Dart logger connecting to NMR device.

Upon finding the logging tool, the main window for logging will display as shown in Figure 26.

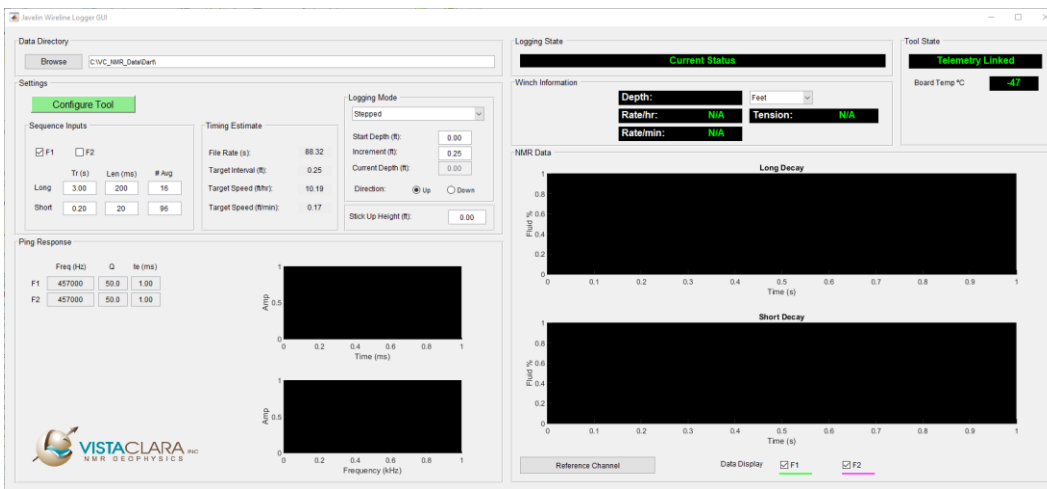


Figure 26: Dart Logger main logging window.

The process for starting a log is listed in the following steps:

**1. Enter a data folder name**

A new folder must always be specified when starting data collection. You can type the folder name directly in the window or you can click the “Browse” button or folder icon for a file navigation dialog box. Raw logging data (see Section 9, Dart Data Formats) will be written to this folder. Data files written to this folder will have the same name as the folder, plus a suffix denoting their order of acquisition.

**NOTICE**

You must specify a new folder that does not contain any Dart data files. Otherwise the folder name will be highlighted and you will not be able to proceed until you specify an empty folder.

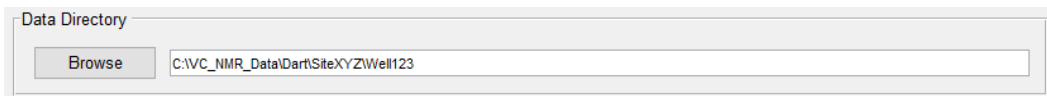


Figure 27: Dart Logger software with directory name specified.

## 2. Choose a logging mode

Two main NMR modes are available: Stepped and Monitoring. Two advanced detection modes are also available: Diffusion and T1. Consult with Vista Clara before using these advanced modes.

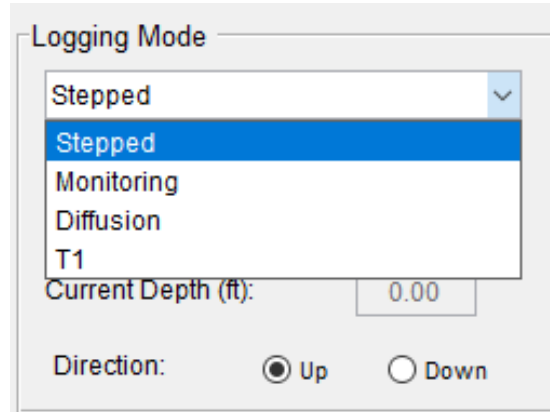


Figure 28: Logging mode selection.

In stepped mode, the probe is held stationary at a fixed depth for one entire data collection cycle. In this mode, the user specifies the starting depth of the probe and the increment in which the tool will be moved.

In monitoring mode, the probe held stationary at a fixed depth for repeated data collection cycles.

### a. Stepped Logging Mode

- i. Select “Stepped” in the Logging Mode panel dropdown.
- ii. In the “Start Depth” box, enter the initial depth of the probe.
- iii. The “Increment” defaults to the height of the measurement zone of the probe. It is not recommended to change this value.
- iv. Select the logging direction by pressing “Up” or “Down”.

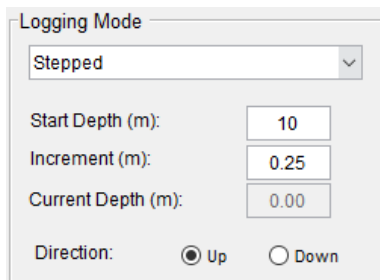


Figure 29: Stepped mode configuration panel.

### b. Monitoring Mode

- i. Select “Monitoring” in the Logging Mode panel dropdown.

- ii. Enter the number of repeat measurements desired.

The image shows a software window titled "Logging Mode". At the top, there is a dropdown menu with "Monitoring" selected. Below this, there are two input fields: "Number of Repeats" with the value "10" and "Current Repeat" with the value "0".

Figure 30: Monitoring mode configuration panel.

### 3. Enter stick-up height (OPTIONAL)

If there is a stick-up height of the well, optionally measure it and enter it into the software in the appropriate panel. The entered stick-up height will be written out with the logging data and appear as an option to subtract from the logged depths during post-processing.

The image shows a software panel with a label "Stick Up Height (ft):" followed by an input field containing the value "0.00".

Figure 31: Stick up height panel.

### 4. Confirm acquisition sequence

The software will by default load the acquisition sequence defined in the calibration files. The values for Tr, # of echoes, and # of averages can be modified prior to starting data collection. See Section 12.2 "Acquisition Sequence Parameters" (page 54) for details on these parameters.

By default, the tool will measure with both operating frequencies (denoted by checkboxes for F1, F2, etc.). To exclude any frequencies from collection, uncheck the corresponding box(es).

Anytime these values are changed the tool must be configured. The software will prompt the user to "Configure Tool" in the button above the sequence inputs.

The image shows a software panel titled "Sequence Inputs". At the top, there are two checkboxes: "F1" (checked) and "F2" (unchecked). Below this is a table with three columns: "Tr (s)", "Len (ms)", and "# Avg". There are two rows of data: "Long" and "Short".

	Tr (s)	Len (ms)	# Avg
Long	3.00	200	16
Short	0.2	20	96

Figure 32: Dart Logger sequence inputs panel with Frequency 2 deselected.

### 5. Send configuration

When the acquisition sequence and data collection mode are entered as desired (or if you are using defaults), click the “Configure Tool” button. This will send the sequence information to the electronics in the downhole probe. This step is required prior to any data collection.

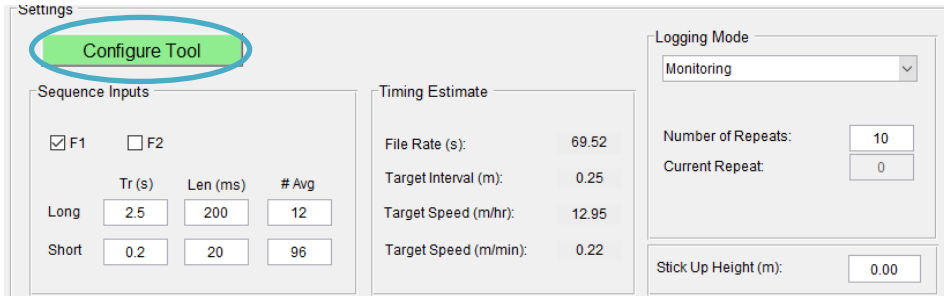


Figure 33: Configure tool button.

The “Logging State” panel will indicate “Configuring Tool...” during this process and notify the user of the current programming step. Wait for the process to complete. The software status will indicate “Ready to Log” when programming of the downhole probe has finished.

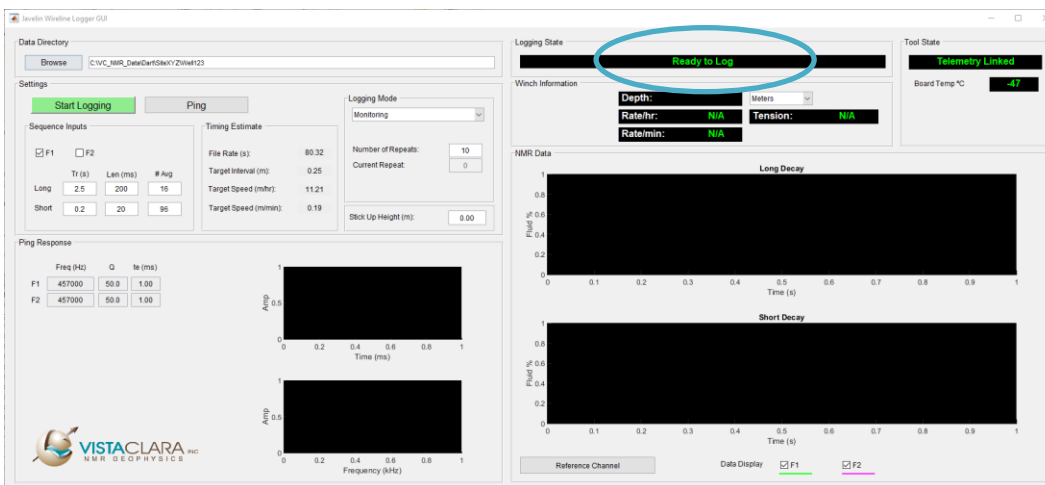
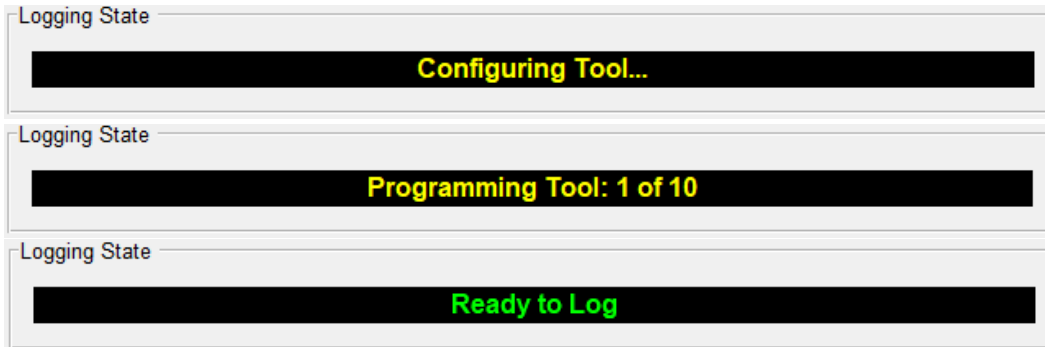


Figure 34: Dart Logger software during transmission of the acquisition parameters to the downhole electronics prior to a data acquisition (top), and after successful transmission (bottom).



If you make any modifications to the acquisition sequence during the same software session, you must click “Configure Tool” for these changes to take effect.

### 6. Diagnostic Ping

The Diagnostic Ping tests the response of the probe electronics, including the resonant coil response and the preamplifier function.

A Ping Test is not required prior to logging. However, it is strongly recommended, as it helps ensure that the system is functioning properly.

Ensure that no metal is in the vicinity of the measurement zone of the probe, which encompasses the lower third of the probe (e.g., metal tool stands).

Click the “Ping” button.

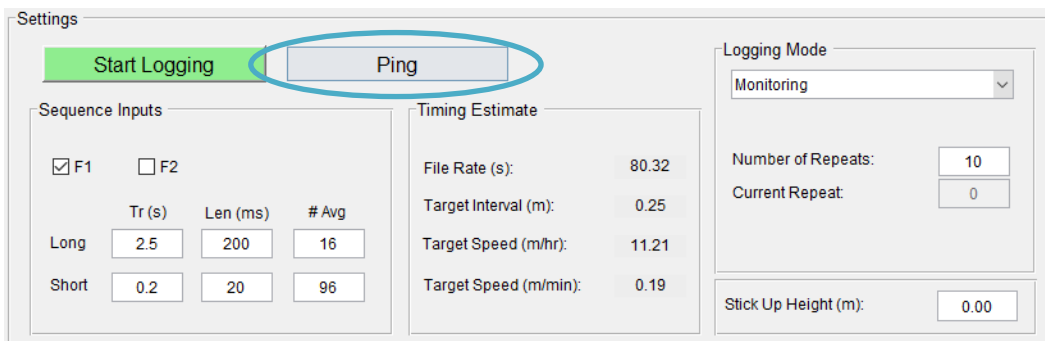


Figure 35: Dart Logger Ping button.

Confirm that the system is returning a successful ping (e.g., Figure 36) before putting the logging probe in the borehole or attempting to start a log.

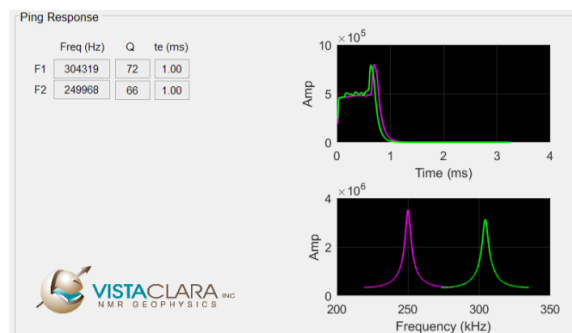


Figure 36: Results of a successful Ping Test.

A good ping response is shown in Figure 36. The upper-right plot shows the time-domain ringdown response of the probe and the lower-right plot shows the frequency-domain ringdown response. The time-domain response should appear as a quasi-exponential ringdown of energy to a low level of background noise. The frequency-domain response should appear as a gaussian peak centered around the known frequency tuning of the probe. In noisy conditions, bursts of noise may be observed in the time domain or noisy

frequency bands may be observed as spikes in the frequency domain. Thus, the ping can provide some indication of the noise level and expected data quality.

If an abnormal ringdown or resonant peak response appear, there may be a problem with the system. Figure 37 shows examples of abnormal Ping responses. Power down the system and computer, recheck all connections, power on the system, check all indicator lights and rerun the ping. If the response still appears abnormal, contact Vista Clara.

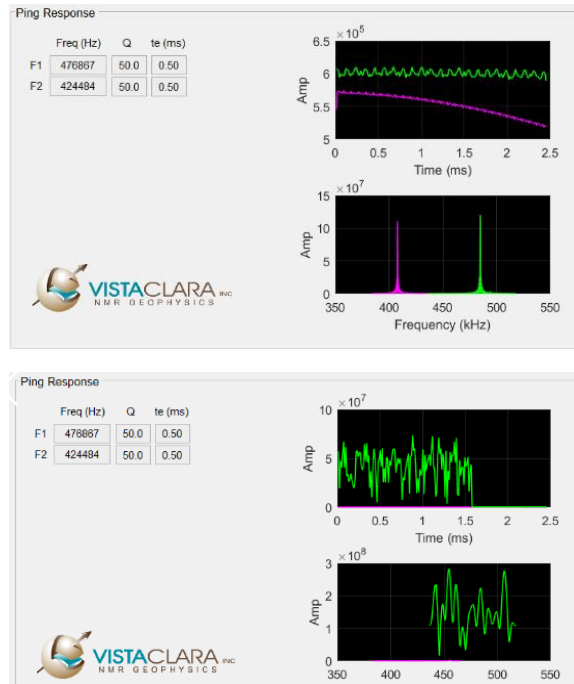


Figure 37: Examples of abnormal Ping responses.

## 7. Starting a log

Click the “Start Logging” button.

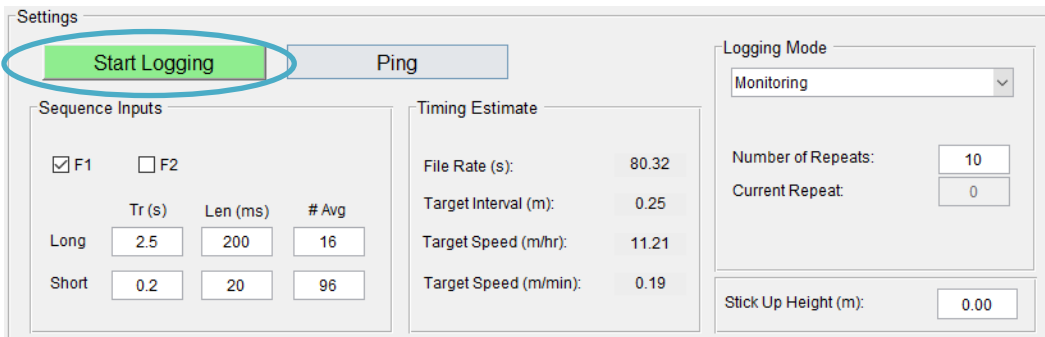


Figure 38: Start logging button.

The system will begin making NMR measurements immediately. Once it has completed its predefined sequence, it will proceed in either Stepped mode or Monitoring mode:

- a. In Stepped mode, a popup will prompt you to raise or lower the probe to the indicated depth (see Figure 39). Once the probe has been moved to this depth, click “Continue.” As soon as you click “Continue,” NMR collection will commence at the new depth. (Click “Stop” to end data collection.)
- b. In Monitoring mode, the system will automatically repeat the acquisition sequence until the desired number of monitoring runs has been reached.

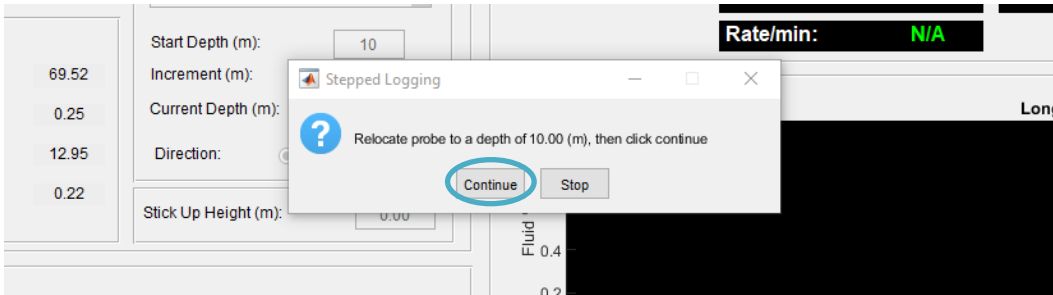


Figure 39: Prompt for raising or lowering probe to a new depth during stepped logging.

## 8. Stopping a log

To stop stepped logging, click the “Stop” button in the dialog box after the software completes the last desired depth step.

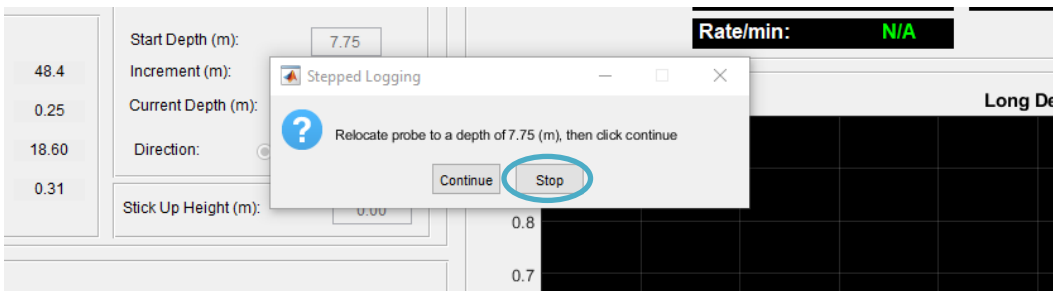


Figure 40: Prompt for stopping log during stepped logging.

Monitoring acquisitions will stop automatically after the indicated number of runs has been completed.

To abort a log during acquisition, click the “Stop Logging” button in the main software window. By default, this will cause the software to stop *after* the conclusion of the current measurement sequence. A “Finishing” notice is yellow will appear, indicating that the current measurement is going to be the last.

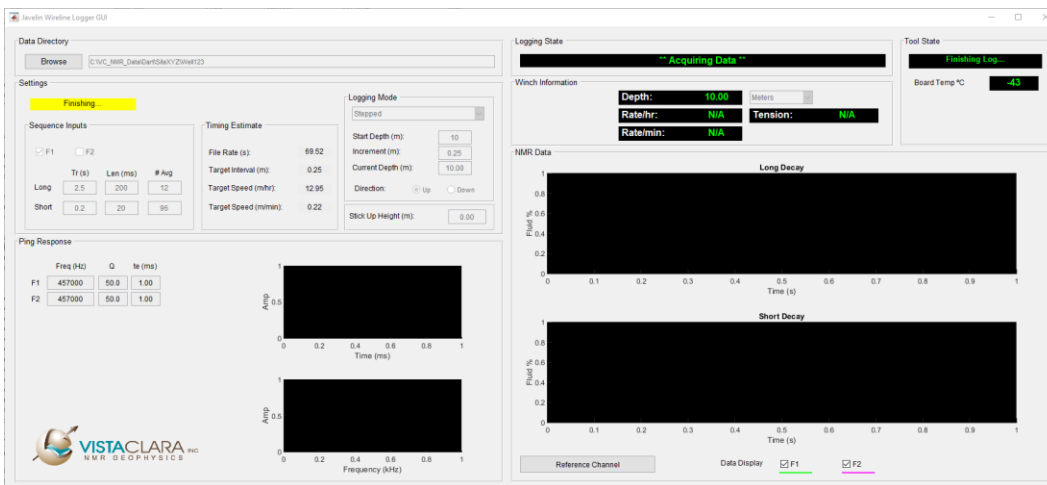
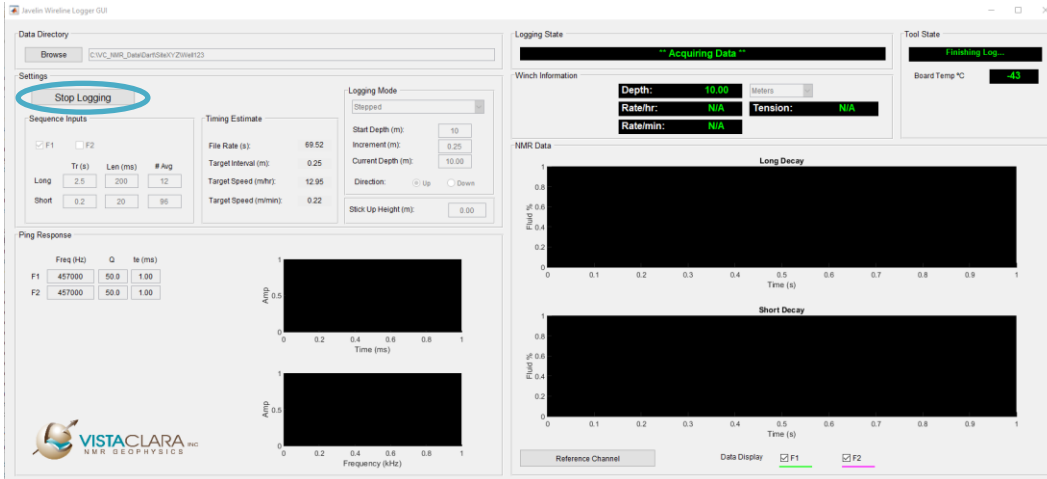


Figure 41: Clicking the "Stop Logging" button will cause the software to stop collection after the current measurement cycle concludes.

## 9. Log timing estimates

The "Timing Estimate" panel shows an estimated file rate and target speeds based on the sequence time and target interval. The target interval is pulled from the calibration file measurement zone of the probe. The target interval can also be updated by changing the increment in Stepped Logging.

This updated software will recalculate the timing estimates based on averaged times as the log progresses. When you begin a continuous log, the first timing estimate will populate based on generic values, but as the second file begins the timing estimates will update to reflect data collected based on your system/computer combination.

As a user begins logging, the first record will only show *estimated* file rates in the "Timing Estimate" panel. These are based on generic values and the length of a CPMG. Once the first measurement is completed, written out, and saved, the timing estimates will update to reflect data collected based on the user's logging system/computer combination. Logging time depends on the system telemetry and computer data

transfer rate which can vary widely due to differing hard drives. The logger will collect these times and average them over the course of the log to provide a more refined timing estimation.

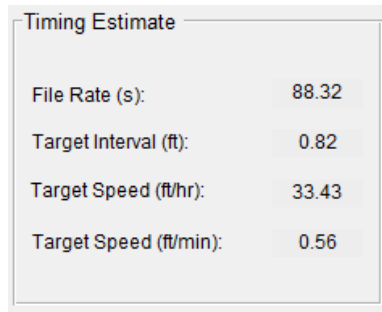


Figure 42: Timing estimate panel showing estimated file rate and target speeds. These values will update after the first log is collected to reflect the average speed of the user's system.

### 10. Reference channel

If the user has purchased an optional reference box, they can view the collected data in real time by toggling between the “Main Channel” and “Reference Channel” button located in the bottom left corner of the NMR Data panel. The reference data will typically look like random noise, but it can be valuable for noise cancellation in post-processing. The reference data will populate per NMR record and if enabled it will also be written out to each JRD record.

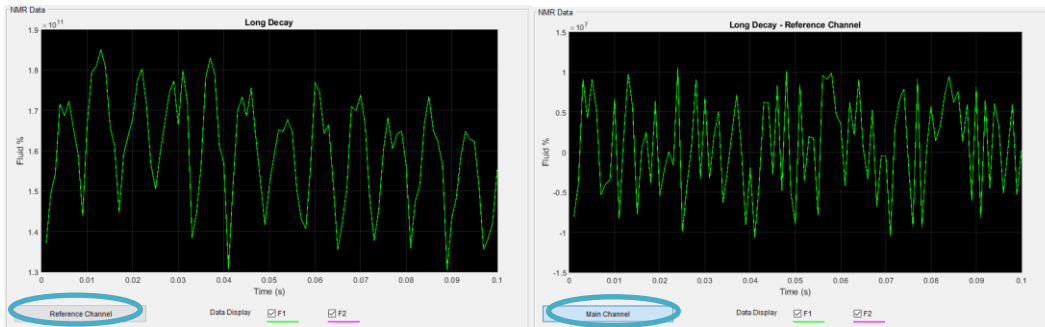


Figure 43: Timing estimate panel showing estimated file rate and target speeds. These values will update after the first log is collected to reflect the average speed of the user's system.

### 7.7 RESTARTING LOGGING FOLLOWING INTERRUPTION

If logging is interrupted, resume the logging in a new data folder. Make field notes of the log start and end depths.

### 7.8 DEPOWERING THE DART SYSTEM

**NOTICE**

DO NOT disconnect any connections until after the Dart system is completely depowered.

Once data collection has completed, exit the Dart Logger or VC\_NMR software. Next press the power button on the Dart Surface Station to depower the system. Before removing the probe from the borehole, store the computer safely so that the computer is not damaged by proximity to the magnets in the Dart Probe.

**To stop the data acquisition sequence in a non-emergency situation:**

To interrupt data acquisition click the “Abort” button. You may need to click the “Abort” button a second time if using Burst mode.

**To stop the data acquisition in an emergency situation:**

To interrupt data acquisition in an emergency, immediately turn off the Dart Control Unit by pressing the power button.

## **8 DART DATA PROCESSING**

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Processing of Dart data is done using the “Javelin Pro Plus” program. This program has separate documentation.

Please refer to the documentation provided with the software for instructions on processing Dart data using this program.

## 9 DART DATA FORMATS

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### 9.1 JAVELIN REDUCED DATA (\*.JRD)

Raw logging data is written to the field laptop as “.JRD” files.

JRD files are tab-delimited ASCII text files. The format of this file is a series of repeating triplet rows, one triplet for each combination of frequency and Tr that was collected.

Each triplet consists of:

- A header row, containing metadata (see Table 1).
- A data row, containing spin echoes (real part).
- A data row, containing spin echoes (imaginary part).

*Table 1: Metadata entries stored in the header row(s) of the raw data files (JRD files). Not all values may be written in all cases.*

Column	Name	Units
1	Tex	s
2	Echo spacing	r
3	Number of Echoes	
4	Transmit Frequency	Hz
5	Number of Averages	
7	Q	
9	Depth	m/ft
14	Tr	s
15	Stick-Up Height	m/ft
19	Sensor offset	m
22	Echo phase shift	
24	Calibration Q	
25	E1 Scale	
26	MF Amp	
27	LV Phase	
28	Frequency Index	
33	Acquisition Platform	
34	Acquisition Software <Major Version>	
35	Acquisition Software <Minor-Version>.<Bug-Fix>	
39	Board Temperature	C
41	Board Clock RTC	s
42	UNIX time	
44	Depth units (0 = meters, 1 = feet, 2 = monitoring, 3 = Tex scan)	
50	Data Acquisition Device (Dart)	

51	FPGA Version	
52	Collection Type	
53	Reference Channel Data Flag	
54	Tool Length Upper	m
55	Tool Length Lower	m
56	Diffusion Time (ms)	ms
57	Inversion Time (ms)	ms
58	Coil Offset Lower	m

## 9.2 CALIBRATION FILES

All calibration files are located in a calibration folder. There should be four calibration files in each calibration folder:

- 1) \*seq\*.ini -- This file may be edited by any user. It contains the sequencing information that is read in by default to the Logger software.
- 2) \*tool\*.ini – This file should not be edited. This file contains calibration information for the specific probe/cable combination being used. The only field in this file that should be changed by the user is the echo spacing. Changing other fields may lead to invalid results and may cause system damage.
- 3) \*sys\*.ini – This file should never be edited by any user. This file specifies interfacing protocols of the DDCU and probe.
- 4) \*winch\*.ini – This file may be edited by users only in the case of direct push logging to enable or disable an integrated depth encoder.



## 10 MAINTENANCE

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**⚠ DANGER**

The Dart instrument generates and stores very large amounts of electrical energy. Attempting to service the Dart internal electronics can cause severe electrical shocks, burns, or even death.



**Any of the following actions by the user are expressly forbidden and will render all warranties void, unless the user has received prior written authorization from Vista Clara.**

- Removal of any Dart Control Unit instrument panel
- Servicing any internal components of the Dart Control Unit
- Opening the Downhole Probe casing
- Servicing or accessing components inside the Downhole Probe
- Servicing or modifying the Custom Downhole Cable
- Servicing or modifying any primary connection cables

**DART HARDWARE CONTAINS TAMPER EVIDENT SYSTEMS THAT WILL INDICATE ANY OCCURANCE OF UNAPPROVED INTERNAL ACCESS.**

Under ordinary circumstances, the customer should not expect to receive authorization for any of the above actions.

Under extraordinary circumstances, Vista Clara will consider such requests subject to the ability of the customer to provide competent electronic technicians trained in the servicing of high voltage power electronics geophysical equipment.

**UNAUTHORIZED SERVICING OR ACCESSING OF COMPONENTS INTERNAL TO THE PRIMARY SYSTEM COMPONENTS OR PRIMARY CONNECTION CABLES IMMEDIATELY VOIDS THE MANUFACTURER'S WARRANTY AND RENDERS THE SYSTEM UNSAFE FOR USE.**

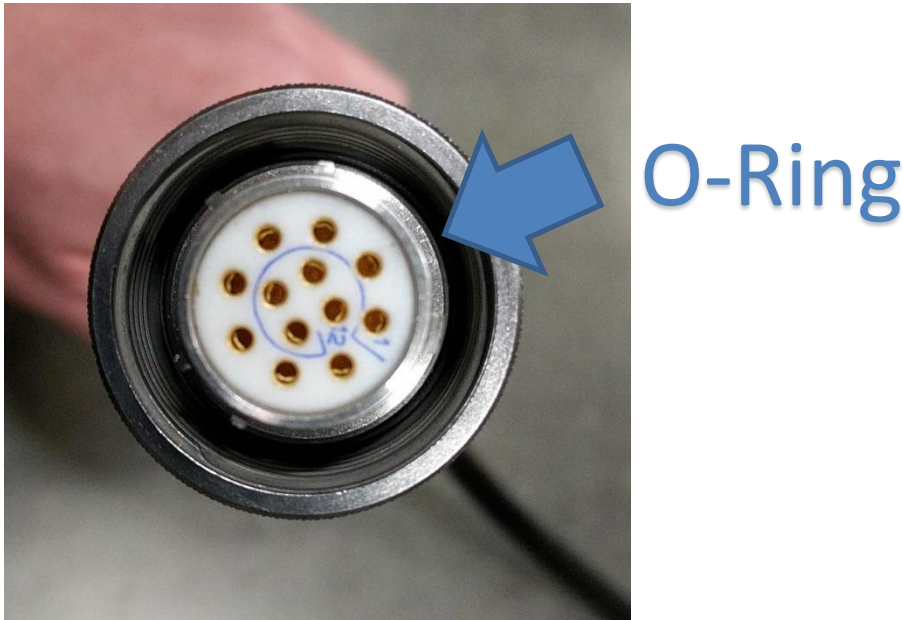
### 10.1 SYSTEM CARE

It is important to provide regular care, maintenance, and inspection of all cases, external surfaces, and connections on the Dart equipment to enhance the operational lifetime of the system and limit the need for repairs.

#### O-rings

The connection between the Downhole Probe and Downhole Cable should always remain clean and well lubricated. Whenever connecting and disconnecting a Downhole Probe, check to ensure that the O-rings are clean and well lubricated. If the connections become dirty, clean them with a soft cloth which may be dampened with isopropyl alcohol. Periodically apply non-conductive vacuum grease (DOW CORNING high vacuum

grease) to the surfaces of the downhole cable connection. In particular, ensure that the O-ring is clean and lubricated.



*Figure 44: Location of O-ring in cable head.*

### **Storage**

After using the instrument, all surfaces and connections on the primary units should be wiped clean of any dirt and moisture, and inspected for damage. Never attempt to clean the system using sprayed water. External surfaces of the instrument (not any of the connection ports) can be cleaned with a damp cloth. If necessary, a mild general purpose detergent without any ammonia may be used (not on any of the connection ports). Flammable residues from any source must never be left on any part of the system to avoid potential fire hazards.

The Dart system should be kept in a clean, dry area when not in use. The Dart system should never be left deployed in the field overnight or unattended. The system should be stored upright and all connections should be dried and then capped. During storage or transport of the system, the individual units should never be tilted beyond 45 degrees from the normal vertical upright position.

Connection Cables should be regularly inspected for any cuts or abrasion to the insulation and/or protective jacket. **If damage is present: the cables are not safe to use.** Contact Vista Clara for instructions on repair or replacement of damaged cables or cable connectors.

Cable connectors must be kept clear of debris, soil, sand, oils, conductive fluids and corrosive agents. If exposed to water, be sure that all connectors are completely dry before replacing caps. Fluid should not be used to clean any the connection ports, however, it is acceptable to use pressurized air to blow out any moisture or particulate

matter from the connections. It is recommended that the user apply a non-conductive, non-reactive silicone lubricant to the exterior threads or bayonet-style slides of the connection ports to reduce connection friction and wear. Do not use a spray applicator as this may discharge lubricant onto the electrical contacts.

**If cuts or significant abrasions to the insulation are observed at any time, the connector cable is unsafe to use. Do not attempt to repair the wire by splicing or by attaching electrical tape. Immediately contact Vista Clara, Inc. to discuss repair or replacement options.**

If any component of the Dart system ceases to function properly, immediately discontinue use and contact Vista Clara, Inc. for further instructions.

## 10.2 SYSTEM SERVICING



WITH THE EXCEPTION OF THE O-RING CONNECTION ON THE DOWNHOLE CABLE AND THE BATTERY FUSES, THE DART CONTAINS NO USER-SERVICEABLE PARTS. UNAUTHORIZED SERVICING OR ACCESSING OF COMPONENTS INTERNAL CONTROL UNIT OR DOWNHOLE PROBES WILL RENDER THE MANUFACTURER'S WARRANTY IMMEDIATELY AND ENTIRELY VOID, AND THE SYSTEM UNSAFE FOR USE. DART HARDWARE CONTAINS TAMPER EVIDENT SYSTEMS THAT WILL INDICATE UNAPPROVED ACCESSING OF INTERNAL COMPONENTS.

Contact Vista Clara for all servicing requirements.



## 11 TROUBLESHOOTING GUIDE

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This section describes basic troubleshooting procedures if the user encounters common problems with the system:

**Problem: Dart NMR Logger program appears non-responsive.**

*Reason #1: The Dart NMR Logger software was terminated improperly.* If the Logger software was terminated using a "hard kill", such as closing the window or using the "abort" control, or if the embedded Data connection was displaced in the middle of a data collection, then the system should be shut down and the computer rebooted.

**Problem: No NMR signal is detected**

*Reason #1: No groundwater is present in the investigated zone.* Some formations (granite) have very little groundwater. Also very little water is likely to be present above the water table.

*Reason #2: Extremely short decay times prevent signal detection.* Water in very fine grained materials (such as certain clays) will exhibit very short decay times (sometimes less than 0.5 ms). As a rule of thumb, the Dart system will only detect water having  $T_2$  decay times greater than  $\frac{1}{2}$  the echo time.

## 12 ADDITIONAL DOCUMENTATION

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### 12.1 OVERVIEW OF NUCLEAR MAGNETIC RESONANCE

The Dart System directly detects the presence of groundwater utilizing a phenomenon known as proton nuclear magnetic resonance (NMR). Proton NMR is observed when protons spins associated with hydrogen atoms in groundwater are subjected to a perturbation in the background magnetic field. In a static magnetic field,  $B_0$ , the proton spins will preferentially align in the same direction as the field and so form a small magnetic moment. In the case of the Dart system, the background field is created by magnets in the probe.

The spin magnetic moments associated groundwater can be excited from their equilibrium state by transmitting an radio-frequency RF pulse at a specifically tuned frequency. This pulse is generated by the probe and causes a portion of the spin magnetization to rotate perpendicular to the background field, into the so-called “transverse plane.” In this excited state, the magnetization will then precess about the background field and generate an RF signal which has the same frequency as the transmitted pulse. This frequency is called the Larmor frequency,  $f_0$ , and it is proportional to the magnitude of the background magnetic field. For hydrogen in water, the Larmor frequency can be calculated as:

$$f_0 = 4258(\text{Hz/Gauss}) * B_0(\text{Gauss}).$$

A series of EM pulses are used to measure the transverse magnetization signal which decay as the spins return to their equilibrium state.

In the basic CPMG experiment, a series of RF pulses are transmitting in short-succession. Between each pulse, an NMR spin echo is measured generating a so called “echo train”. The time spacing between each pulse (also the duration between each echo signal is known as the “echo-time”. The center frequency of the spin echo signal is the Larmor frequency. The intial amplitude of spin echo train is directly proportional number of proton spins being measured (i.e. the amount of water). The echo train exhibits a decay over time characterized by the decay time  $T_2$  (typically between 1ms and 1s). The  $T_2$  decay time provides information about the pore-scale environment of the spins and can be used to derive estimates of pore size and permeability.

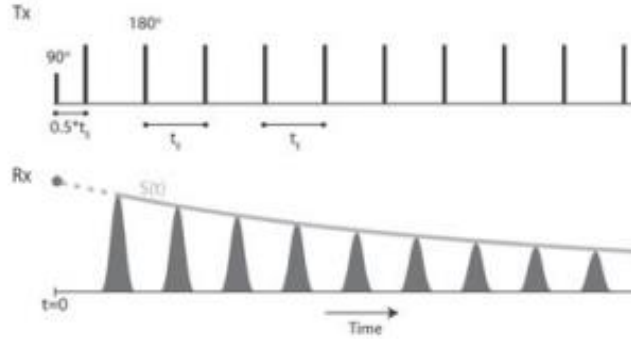


Figure 1. Schematic illustration of the CPMG pulse sequence showing timing of transmitted  $B_1$  pulses in the top panel, and received NMR echo signals (dark gray) in the bottom panel. The lighter gray line represents the spin echo decay curve  $S(t)$  with an initial amplitude proportional to water content and an exponential decay time  $T_2$ .

As the Dart probe is lowered into the formation, multiple CPMG measurements are collected (or “stacked”) at each depth interval. After a series of measurements are collected at one depth interval, the probe is lowered and another series of measurements is collected to generate an NMR depth log used for interpretation.

## 12.2 ACQUISITION SEQUENCE PARAMETERS

An example logging measurement sequence is shown below. At a given depth level, one or more stages of measurement are performed. The stages are comprised of scans at different frequencies (“F1”, “F2”...), and each scan is repeated to form multiple measurement averages. What differs between each stage is the time between each repeated measurement average (“Tr”) and the length of each measurement scan (“Scan”); also each stage may include a different number of averages. The practical

importance of these sequence parameters is described briefly below.

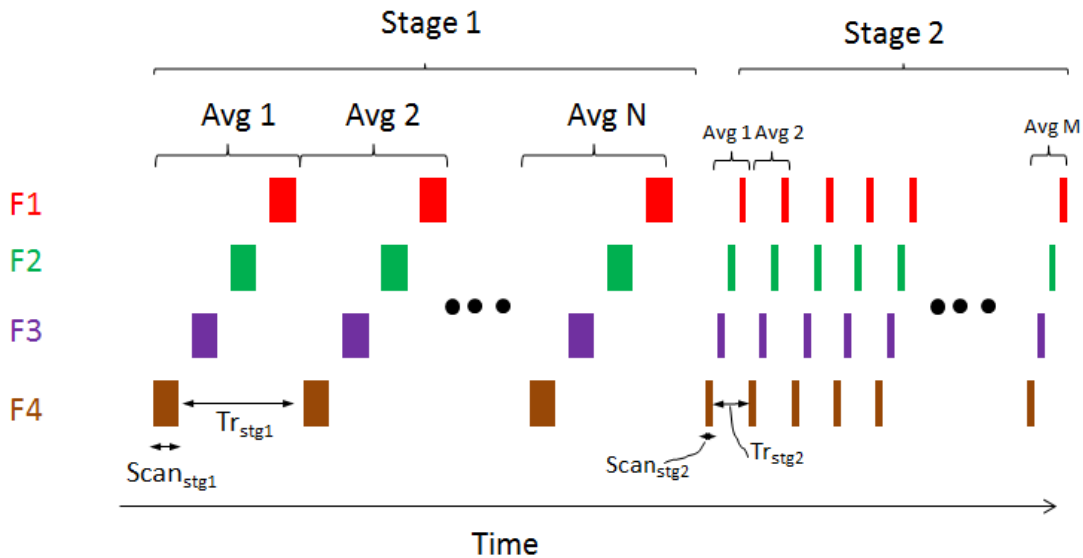


Figure 45: An example sequencing setting showing the use of multiple measurement frequencies and multiple averaging stages.

**-Frequency:** The Dart probes can operate at two or four different frequencies. Lower frequency measurements provide sensitivity at a maximum radial depth of investigation. The higher frequency measurements provide a radial depth of investigation slightly closer to the probe (by approximately 0.5-1 cm per frequency step). In general, it is advantageous to perform measurements at as many frequencies as possible to increase the amount of data acquired in a given time interval or logging speed.

**-Tr:** The recovery time controls the amount of time between successive CPMG measurement scans at a given measurement frequency. The value of Tr will determine how much time is allowed for water in the formation to recover between measurements. If Tr is set to a long value, all the water in the formation will recover between measurements and all water will be detected. If Tr is set to a short value, only the water with short relaxation times (fast recovery time) will be measured accurately and water with long relaxation times (slow recovery) will be muted. A Tr value of 10 will allow complete recovery for any type of water regardless of formation, but will yield a slower logging speed (long time between measurements). A Tr of 0.5 second will allow much faster logging and will allow complete recovery/detection of water in silty formations, but may result in underestimation of water in unexpected coarse layers. To balance the advantages of long and short Tr values, data are often acquired in a multi-Tr mode as shown above: A few averages are acquired with a long Tr to accurately detect water in large pores with long T<sub>2</sub> and many more averages are acquired with short Tr to accurately detect and resolve water in small pores with short T<sub>2</sub>.

**-Scan Length:** The scan length is the length of each CPMG. As the value of Tr is decreased, the scan length must also be decreased so that the total measurement duty

cycle does not exceed a recommended value. In general, the following equation should be satisfied to avoid errors:

$$(\text{\#frequencies}) * (\text{scan\_length}) / T_r \leq 0.2$$

- ***#Averages***: The number of averages is the number of complete CPMG scans collected at each depth interval using the user specified  $T_r$ . Increasing this number will increase the signal to noise of the log but will also increase the total acquisition time. It is recommended that a larger number of averages be used for formations with low water content or for very shallow surveys which may be affected by cultural noise. A suggested value for #Averages is 50. Doubling the #Averages will double the survey time but will also increase the signal to noise ratio by a factor of approximately  $\sqrt{2}$ .

- ***Echo Spacing***: The echo spacing is the time delay between transmitted refocusing pulses and is also the spacing between receive NMR spin echo signals. Using the shortest “default” echo spacing will provide higher signal to noise and will decrease the influence on diffusion on measured relaxation times. Only expert users should change the echo spacing from the default value. Refer to table Table 1 in the Appendix for a list of default echo spacings for a each probe.

**Adjusting Sequence Parameters** : The sequence parameters can be adjusted either by changing the sequenc file in the calibration folder. They can also be changed directly in the logging software by disabling use of the sequence file. It is suggested that if a new sequence will be used repeatedly (e.g. for a survey with many holes in a particular geology), the sequence file should be updated. If the sequence is being changed for only one log, it is best to adjust the sequence in the logging software.

## 12.3 SAFETY INFORMATION

The Dart system is designed for the sole purpose of conducting NMR logging investigations. The system is only approved for use as specifically outlined in this Manual. Unsanctioned or improper use of the system can result in physical damage to the instrument, personal injury, or even death. It is the responsibility of the owner to ensure that any person using the instrument is qualified and capable of safely operating the system.

In order to ensure safe operation of the system, a qualified operator should have read the complete contents of the Manual and Documentation, and also must have been provided extensive on-site training by an experienced user (Vista Clara recommends a minimum of 3 days). The owner of the system should develop a formal training course to properly train additional operators of the Dart instrument. The system should never be operated by minors or any person under the influence of drugs or alcohol.

The Dart system should be operated only by geoscientists or engineers who have previous experience operating geophysical instruments in the field.



## **12.4 SAFETY CHECKLIST**

**The following safety checklist should be reviewed by all users and field assistants prior to handling or operating the Dart system:**

Always be aware of the strong magnetic fields surrounding the downhole probes.

Do not allow magnetic objects (such as steel) near the probes.

Do not allow persons with implanted medical device, such as defibrillators or pacemakers within 5 meters of any instrument components.

Always secure probes inside steel shielding tubes and secure other steel objects during transport.

Do not connect or disconnect the, Downhole Cable, or Downhole probe when the system is powered on.

Ensure that all connection ports are capped when not connected to cables.

The Dart system should never be left deployed in the field overnight or unattended.

Do not attempt to operate the system if there is damage to the Downhole Cable, or damage to any other parts.

Always check the O-rings on the downhole cable connection to ensure they are clean and free of any dirt or debris. Apply vacuum grease if they O-rings require lubrication.

Always check the system for damage before use. Do not attempt to use the system if any case, seal, meter, connector, or cable is visibly damaged.

Do not stand or sit or place any heavy objects on any of the cases, even when closed. Do not stack cases on each other.

Do not use the system if there is a chance of electrical storms with lightning. The user must respond responsibly to changing weather conditions and discontinue use before a danger becomes present. If lightning is nearby, abandon the system without regard to its current state and seek shelter immediately!

## **12.5 HAZARDOUS MATERIALS**

All components included the Dart system are RoHS compliant. Batteries are not included with the system but may contain hazardous chemicals. Batteries should be handled and disposed of in a safe manner as prescribed by the battery manufacturer.

## **12.6 STORAGE, TRANSPORT, AND HANDLING**

The following guidelines for storage, transport, and handling must be followed to maximize the lifetime of your Dart system and to prevent unnecessary hazards from arising.

Magnets in the downhole probes create strong magnetic fields that are always present, even when now power is connected. Use caution when transporting the probes. Do not allow magnetic objects (such as steel) near the probes; magnetic objects and probes will be attracted and may become projectiles if not properly secured. Magnetic fields can cause damage to electronics and devices with magnetic encoding (e.g., hard drives and credit cards); keep all such objects away from probes.

During storage, all panels on the instrument should be covered and all ports should be capped. The Dart system should only be stored indoors; no component of the system should ever be left outdoors or unattended. The storage environment must be dry and maintain a temperature between -20°C and 50°C with a relative humidity of less than 95% non-condensing. The storage space should be free of rodents or other pests that are known to bite or otherwise damage the insulation material on electrical cables. Components should never be stacked, nor have heavy items placed upon them. Any structures or shelving used to support instrument components must be appropriately rated for the load to be carried.

During transport, the Dart system should be treated and handled as sensitive electronic equipment. When placed in any vehicle for transport, the system should be well-secured to prevent sliding. Additionally, padding should be placed under and between instrument components to prevent them from banging against one another or against other objects; connectors and external ports can be easily damaged as a result of such impacts. When traveling on rough roads, transport the system in vehicles with adequate suspension and drive slowly to avoid unnecessary bouncing or vibration. If extensive transport in rough conditions is required, ensure that the instrument components are adequately packaged, with soft padding and a hard outer casing, to resist shock and hard impact.

## 12.7 PARTS AND ACCESSORIES REQUIRED FOR DIRECT PUSH DEPLOYMENT





Specialized tooling required for Direct Push deployment is listed in this section.

### 12.7.1 Required parts provided by Vista Clara

Parts in Table 2 are manufactured by Geoprobe and provided by Vista Clara with all Dart Direct Push systems in the quantities listed.

These parts are **required** to deploy the NMR system in a Direct Push scenario, with the exception of the Wireless Depth Interface, which is not required if manual depth tracking is used during logging. (The Wireless Depth Interface is not functional without additional components listed in section 12.7.3 “Optional parts for depth tracking” below.)

*Table 2: Direct Push accessories provided by Vista Clara.*





<u>GP P/N</u>	<u>Part</u>	<u>Image</u>	<u>Qty</u>
238997	NMR DP140 Cable Clamp Asm	 <p>NMR JP140 CABLE CLAMP ASM MN: 238997</p>	2
238268	NMR Ext Rod LH Adapter	 <p>NMR EXT ROD LH ADAPTER MN: 238268</p>	2
239182	Drive Shoe		2
240274	Wireless Depth Interface, Depth Measurement Accessory		1

### 12.7.2 Required parts provided by end-user

Parts in Table 3 are manufactured by GeoProbe and are **not** provided by Vista Clara. These parts should be sourced directly from GeoProbe or a GeoProbe Distributor. Vista Clara does not provide or sell these parts.

These parts are **required** to deploy the NMR system in a Direct Push scenario.

*Table 3: Geoprobe small parts provided by end-user.*


<u>GP P/N</u>	<u>Part</u>	<u>Image</u>	<u>Suggested Quantity (notes)</u>
213789	Expendable Points, 2.25", with O-rings, 25-pack		25 (one expendable point and O-ring will be consumed per log)
201352	Extension Rod SS (60in.)  <i>Also available in the following lengths:</i> 1m (P/N 213835) 36in (P/N 213832) 48in (P/N 213833)		20 (20x 5' extension rods allow deployment of the probe to 100')
213839	Extension Rod Quick Link Box		20 (1x required for each Extension Rod)
213838	Extension Rod Quick Link Pin		20 (1x required for each Extension Rod)

### 12.7.3 Optional parts for depth tracking

Parts in Table 4 are manufactured by GeoProbe and are **not** provided by Vista Clara. These parts should be sourced directly from GeoProbe or a GeoProbe Distributor. Vista Clara does not provide or sell these parts.

These parts are **optional** and are used for automated depth tracking<sup>3</sup>. These parts operate in conjunction with the Wireless Depth Interface (P/N 240274), which **is** supplied by Vista Clara. Figure 46 illustrates the deployment of the stringpot depth counter<sup>4</sup>.

Table 4: Optional GeoProbe parts for automated depth tracking.

<u>GP P/N</u>	<u>Part</u>	<u>Image</u>	<u>Suggested Quantity</u>
214227	Stringpot ASM 100" cable		1
220775	Stringpot Ground Plate		1
214228	Stringpot Cordset 30ft  <i>Also available in 65ft &amp; 100ft lengths.</i>		1

<sup>3</sup> For more information, see: <https://geoprobe.com/direct-image/di-accessories/stringpot-and-accessories>.

<sup>4</sup> An alternate, quadrature-based depth counter is also available from Geoprobe and operates with the Wireless Depth Interface P/N 240274. A different cord and ground plate are required for the quadrature-based depth counter. Consult with your Geoprobe representative regarding the choice of stringpot or quadrature depth encoders.

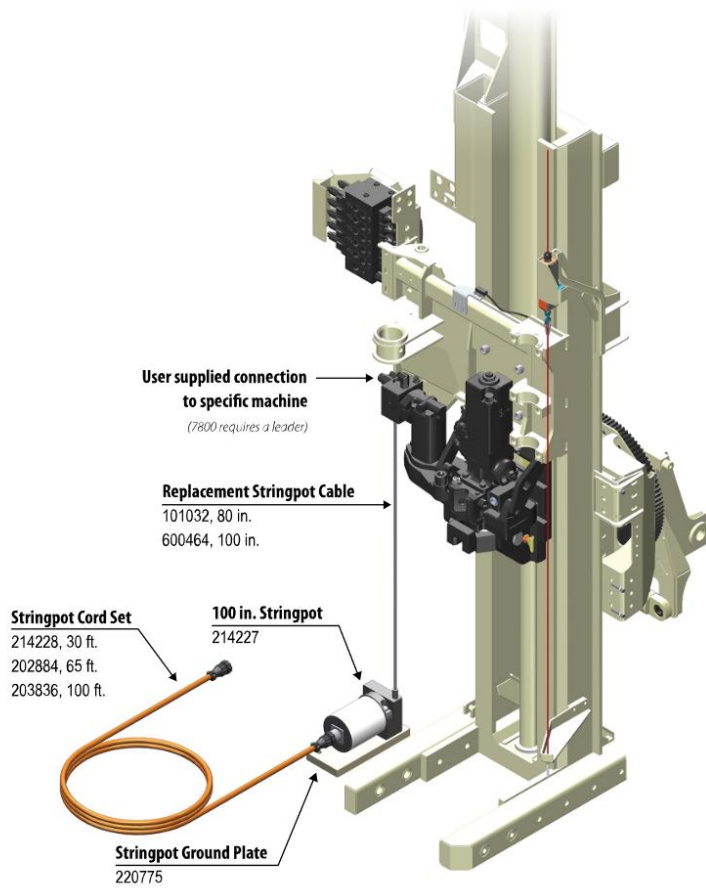


Figure 46: Deployment of string pot depth counter (courtesy of GeoProbe).




**12.7.4 Required parts provided by end-user or contractor**

Parts in Table 5 are manufactured by GeoProbe and are **not** provided by Vista Clara. These parts should be sourced directly from GeoProbe or a GeoProbe Distributor. Vista Clara does not provide or sell these parts.

These parts are **required** during logging operations and are typically provided by Geoprobe operators. If you are contracting with a Geoprobe operator, confirm that they will supply these parts. If you are purchasing a GeoProbe drill rig or wish to own a complete set of all required tooling, you should purchase these parts.

Standard 2.25" rods are widely used by Geoprobe operators<sup>5</sup>. In addition to standard length 5' rods (60"), it may be helpful to also have one or two rods in 1ft or 2ft lengths to make probe insertion/extraction easier. Geoprobe operators may not have these shorter rods, so you may wish to purchase these yourself.

*Table 5: Geoprobe 2.25" parts provided by end-user or drilling contractor.*

<u>GP P/N</u>	<u>Part</u>	<u>Image</u>	<u>Suggested Quantity (notes)</u>
<i>Consult w/ GP</i>	Rod Grip Puller, 2.25"		1
<i>Consult w/ GP</i>	Drive Cap, 2.25"		1
<i>Consult w/ GP</i>	2.25 in. Probe Rod (60 in.)		15 (Operators may use shorter rods but total number and length will determine depth)
<i>Consult w/ GP</i>	2.25 in. Probe Rod (24 in.)	24 in. 	1-2

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<sup>5</sup> Note on rod condition: The inner lip of the rods **must** be free from edges, burrs, or mushrooming which can prevent the probe from passing through during the push-down phase. If possible, new rods should be used and heavily worn rods avoided. Each rod must be inspected, and any excess material filed or ground away. GeoProbe contractors should be made aware of this requirement prior to mobilization.

### **12.7.5 Optional parts provided by end-user or contractor**

Parts in this list may be helpful during logging operations, and may be provided by Geoprobe operators. If you are contracting a Geoprobe driller, confirm whether they will supply these parts. If you wish to own a complete set of all required tooling, you may wish to purchase these parts directly from Geoprobe or a Geoprobe distributor. Vista Clara does not provide or sell these parts.

- A 2.25" "Rod Wiper" may be useful for wiping mud off the rods as they are pulled out of the ground. Rod wipers and adapters to Geoprobe drilling systems are available from Geoprobe.
- In environments where the 2.25" rods must be hammered very hard, there is some potential for the expendable point to get stuck in the Drive Shoe to the extent that it is not possible to expend the point using the NMR probe and Extension Rod string. In this case, a full set of 1.25" rods can be inserted through the 2.25" rod string to TD and used to eject the Expendable Point. In this case, operators would need a full set of 1.25" rods to reach total depth, a 1.25" drive cap, rod lifting adapters, and any other required 1.25" tooling.



## **13 CONTACT INFORMATION**

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Vista Clara, Inc.

12201 Cyrus Way, Suite 104,

Mukilteo, WA, USA 98275

For fastest contact with Vista Clara Inc., please phone, fax, or email. Check our website frequently for changes of address and other contact information: [www.vista-clara.com](http://www.vista-clara.com). If contact information is changed on our website, record the new contact information here on this page of this manual, and strike the any outdated contact information.

Phone:

+1 (425) 493-8122

Fax:

+1 (425) 493-8223

Email:

[info@vista-clara.com](mailto:info@vista-clara.com)

**2016/42/EC Machinery**  
**2016/95/EC Low Voltage**  
**DECLARATION OF CONFORMITY**

**Name of Manufacturer**

Vista Clara, Inc.

**Full postal address, including country of origin**

12201 Cyrus Way, Suite 104,  
Mukilteo, WA, USA 98275  
United States of America

**Description of Product**

Instrument for the characterization of underground water

**Name, type, model, and serial number**

Type: Instrument

Model: Dart

Supply: 12 VDC

Country of Origin: USA

Make: Vista Clara

Location: Mukilteo, Washington, USA

Reference: CD2016-10

**European Normalized Standards Applied**

EN 292-2:1991	Basic concepts, general principles for design – Technical principles and specifications
EN 60204-1:2005	Basic concepts, general principles for design – Technical principles and specifications
UL 61010-1:2008	Standard for Safety, Electrical Equipment for Measurement, Control, and Laboratory Use
ISO 14121	Safety of Machinery – Risk Assessment (formerly EN1050:1997)
ISO 3864	Safety colours and safety signs
NFPA 70-2008	National Electric Code
NFPA 79-2007	Electrical Standard for Industrial Machinery

**Manufacturer**

Place of issue

USA

Date of issue: October 24, 2016

**Title of signatory**

**Name**

**Signature**

President

David Walsh

  
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**DECLARATION OF  
CONFORMITY**

**2016/42/EC Machinery**

**2016/95/EC Low Voltage**

Declaration

I declare that as the authorized representative, the above information in relation to the supply and manufacture of this product, is in conformity with the stated standards and other related documents following the provisions of the above Directives and their amendments.

Copies of the Technical File are kept by the authorized representative for inspection by enforcement authorities.