US Academic Research Fleet (ARF) Launch And Recovery System (LARS) Systems & Recent Incidents

Revised 12 November 2024

Introduction

Several modern ships in the UNOLS fleet have automated Launch And Recovery Systems (LARS) that are dedicated to CTD operations. The two main components of a LARS are a handling winch and overboarding mechanism such as a boom, crane, A-frame, or J-frame. Like most modern machinery, electric winches are controlled by an industrial computer called a Programmable Logic Controller (PLC), which sends signals to the winch motors via Variable Frequency Drives (VFDs). This in turn makes the winch capable of automatic rendering (auto-render). The winch has different auto-render modes that can respond to sensor measurements such as line tension, velocity, or target proximity. Feedback controls move the winch automatically, whether it is to set line tension at a constant value, or compensate for vessel motion to reduce tension spikes. Auto-render has the potential to make operations safer if used correctly.

This report examines several CTD-LARS incidents that have been reported since their introduction into the U.S. Academic Research Fleet (ARF) ten years ago. Most of the information was gathered from an incident review meeting held virtually on July 14, 2021. A working group was formed in late 2023, with the first task being to complete this report so it can be disseminated to the UNOLS community. We have provided a summary of findings and recommendations for possible ways to make LARS operate safer.

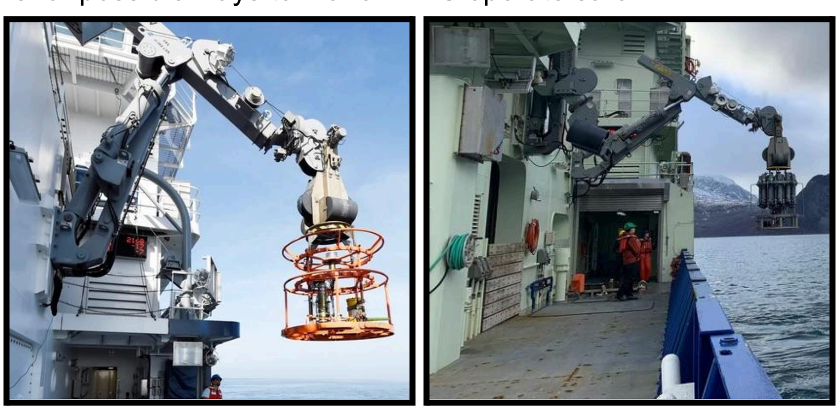


Figure 1 - The automated LARS cranes on R/V Sally Ride (left) and R/V Neil Armstrong (right) were manufactured by Allied. The winches are not pictured.

Terms, acronyms and abbreviations

ARF: U.S. Academic Research Fleet.
Auto render: LARS automation setting that limits line tension by winch payout
Auto winch: see “Auto render”.
Auto with LARS: see “Auto render”. The Hawboldt system operates “auto with LARS”, an automation feature that facilitates automatic winch response when moving the crane. It is built on PLC/VFD logics and a boom sheave encoder.
Belly pack: A remote control, typically wireless and tethered to the operator allowing mobile operation with both hands.
Boom: the main arm of a crane or other lifting system that bears most of the weight of the load and primarily determines the reach of the crane.
CTD: An instrument package for measuring Conductivity, Temperature and Depth, and pressure, raised and lowered through the water column via a conducting tension member. Frequently associated with an array of sampling bottles (see “**rosette**”).
Constant tension: a LARS automation feature that operates a winch to automatically maintain a specified tension on the tension member typically via torque control.
Docking: securing a package (e.g. CTD rosette) pre- or post-deployment to the LHS.
Docking head: a mechanism against which a package is seated and held in place either mechanically or by putting constant tension on the tension member.
Encoder: A sensor that communicates information related to rotary or linear movement and/or position between two components.
Jib: The horizontal or near-horizontal beam used in many types of crane to support the load clear of the main support, a secondary arm that extends off the end of a boom.
JMS: JMS Naval Architects - Vendor responsible for NSF inspections.
LARS: Launch And Recovery System.
LHS: Load handling system - Any piece of equipment or collection of equipment that are used collectively to reposition equipment on deck, for the purpose of this document winches are not included in the term.
NSF: National Science Foundation.
OHS: Overboard Handling System - A system used to tow objects, to lower them beneath the surface of the water, or to retrieve them from beneath the surface of the water. A system is only considered an OHS if it features a tension member coupling the object and vessel, and payed beneath the surface of the water.
PLC: Programmable Logic Controller - the main component of a control system used with modern machinery.
RCRV: Regional Class Research Vessel.
Termination: The finished working end of the tension member.
Rosette: An array of sampling bottles, raised and lowered through the water column via a conducting tension member. Frequently sharing the same frame as the CTD instrument package (see “**CTD**”).
Tension member: the weight bearing wire or cable of a load handling system.
VFD: Variable Frequency Drive - used for fine control of electric motors.

Academic Research Fleet (ARF) Launch And Recovery Systems (LARS)

Ship	Winch manufacturer	Crane manufacturer
R/V Sikuliaq	RAPP	Triplex
R/V Roger Revelle	Markey	Allied
R/V Sally Ride	Markey	Allied
R/V Armstrong	Markey	Allied
R/V Kilo Moana	Hawboldt	Hawboldt
R/V Hugh Sharp	Caley	Caley

LARS operation during Launch and Recovery

RV SIKULIAQ

How the system is currently used:

The Load Handling System (LHS) on the R/V Sikuliaq features a spring-loaded docking head at the end of the boom. This docking head includes multiple proximity switches designed to detect when the CTD package is correctly positioned within it.

During both launch and recovery, the operator manually operates the winch to pull the CTD package into the docking head. Once the package is in position, the operator activates the "constant tension" mode on the control computer. This mode applies a minimum tension to the cable, compressing the docking head springs and securing the CTD rosette in place. In this state, the winch operations are coupled with the boom operations, meaning the winch automatically adjusts cable pay-out or retrieval to maintain consistent compression on the docking head springs. To lower the package, the operator adjusts the boom position, *deactivates* the constant tension mode, and manually pays out the winch to release the package from the docking head.

How the system was intended to be used:

The original system was designed without multiple proximity switches (refer to System Failsafes below) and included both a minimum and maximum constant tension value. This setup was intended to restrict the amount of automatic compensation applied to the docking head, allowing for a range of tensions during launch and recovery.

However, this approach led to several issues: (1) the package exhibited continuous movement within the docking head due to fluctuating spring compression and cable tension, and (2) the system occasionally reached tension levels deemed excessive for safe launch and recovery. As a result, the system underwent some minor modifications between 2016-2018 to address these problems.

System failsafes:

The RV SIkuliaq's Load Handling System (LHS)'s docking head is equipped with multiple proximity switches for detecting when the springs are compressed too much. When one proximity switch is triggered, the winch is hook-stopped so it cannot haul-in. When the next proximity switch is triggered, the system prevents the LHS from moving in a direction that would increase docking head compression and cable tension further. Once the proximity switches are no longer triggered, the system is fully functional again.

RV ROGER REVELLE, RV SALLY RIDE, RV NEIL ARMSTRONG

How the system is currently used:

The Load Handling Systems (LHS) on the RVs Roger Revelle, Sally Ride, and Neil Armstrong are equipped with a spring-loaded docking head at the end of the boom. This docking head features proximity switches to measure the distance of the CTD rosette from the docking head.

To launch a package, the operator first manually positions the handling boom over the CTD rosette. Then, the system is switched to "Auto-Mode" and the operator uses the winch to bring the package into the docking head until the lower proximity switch indicates sufficient spring compression. Once triggered, the package is considered "docked" and is securely held. The winch operation is then coupled with the boom's movement, automatically paying out or hauling in cable to maintain proper compression on the docking head. During this process, motor torque values are continuously monitored to stay within predefined limits. The operator then activates the handling system "launch", and the boom automatically moves the package from the ship to the cast position over the water. For recovery, the operator activates the handling system "retrieve" to reverse the process.

How the system was intended to be used:
The system is used as it was intended to be used.

System Safety Measures / Failsafes:
As a safety measure, when the the system is in auto-mode, winch speed is limited to 10-15 meters per minute. This limits the speed with which the rosette can approach into the docking head.

Additionally, the RV Neil Armstrong's Load Handling System (LHS)'s docking head is equipped with redundant proximity switches in case there is a switch failure.

RV KILO MOANA

How the system is currently used:

The RV Kilo Moana's Hawboldt overboard handling system (OHS) features an OS42 oceanographic winch and a telescopic knuckle boom crane, specifically a 2.5-ton CTD Launch and Recovery System (LARS). The LARS is equipped with a spring-loaded docking head at the end of the boom. Above the docking head is the overboarding sheave with an integrated encoder.

During CTD rosette deployment, the LARS is positioned so that the docking head is directly above the CTD rosette bridle, with approximately 3-6 feet of clearance between them. The operator manually hauls in on the winch until the CTD rosette is securely docked in the docking head. Once docking is complete, the operator switches the system to “Auto with LARS” mode. In “Auto with LARS” mode, the winch operations are coupled to the crane’s operation; the winch automatically adjusts by hauling in or paying out as needed to keep the CTD rosette securely positioned in the docking head as the crane is maneuvered.

In contrast to other LARS within the fleet, this particular system utilizes an encoder integrated into the sheave positioned above the docking head to facilitate coupling. The user specifies the desired distance between the tip of the docking head and the overboarding package for each operation. The control system uses the encoder to accurately measure the linear displacement between the package and the boom tip. This displacement data is employed within a closed-loop feedback control mechanism, enabling the winch to continuously adjust in order to minimize any discrepancy in displacement measured at the boom tip. Consequently, this system operates with reduced tension compared to traditional LARS configurations, thereby decreasing the mechanical strain and enhancing operational safety.

How the system was intended to be used:
The system is being used as intended.

System Failsafes:
The Hawboldt OHS includes a number of failsafes within the control system. There are two proximity switches on the LARS docking head. If the CTD rosette approaches a two-block situation, the proximity sensors are activated, causing an immediate halt to all system operations.

Incident Summaries

R/V Sikuliaq (UAF) – 12 Sep, 2014

This incident occurred during the vessel's initial NSF-JMS inspection, which occurred even before the vessel began deepwater sea trials.   At this stage, all operators were inexperienced with the R/V Sikuliaq's overboarding operations, which was a contributing factor to the incident.

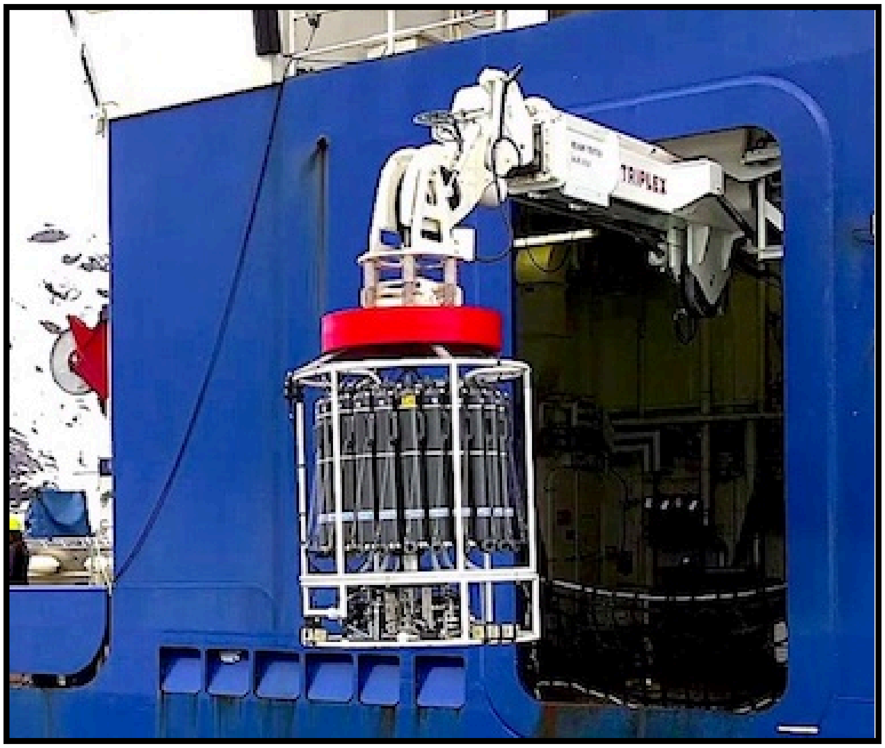


Figure 2 - Sikuliaq's CTD rosette in the LHS docking head.

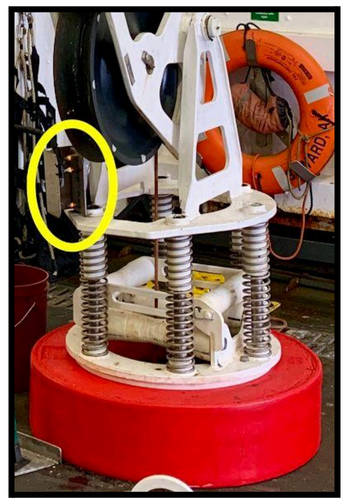
The R/V Sikuliaq is equipped with two direct-drive winches, each controllable from either of two winch control stations, depending on the operation. At the time of the incident, the winch control stations, configured by the manufacturer RAPP, were capable of interfacing with multiple winches from each station. When correctly set up, both the joystick and the software controlling constant tension are aligned with the same winch at the control station.

During the incident, while the joystick was properly set to the correct winch, the software was configured for a different winch. The operator proceeded to haul the CTD package into the docking head and activated auto-tension mode. At this stage, winch operations should have been coupled with the crane operations. However, due to the software mismatch, constant tension was applied to the incorrect winch, meaning that winch and boom operations were not properly coupled.

When the operator used the joystick to move the boom outward, they assumed the software would automatically adjust the winch accordingly. Since the winch connected to the CTD rosette was not actually in constant tension mode, as the boom was trolleyed outboard for deployment, the winch did not move, the springs on the docking head became fully compressed. This created excessive tension on the cable, exceeding its elastic limit until it failed and parted. Consequently, the CTD rosette fell from the docking head, initially landing on the edge of the door frame before falling overboard, resulting in a total loss.

Corrective Actions:

- The winch control stations are set to only control the one winch that is relevant to the operation performed from that particular station.
- The *hydrographic* winch was renamed Winch 1, and the *CTD* winch was renamed Winch 2. All labels, signs, and placards were changed accordingly.
- Proximity switches located on the docking head (circled in yellow) were integrated with the LHS controls. If the springs compress too much, relays will lockout the hydraulic spool valves so the boom cannot move in a direction that would continue to increase tension.
- The constant tension limit is manually set by the operator for each deployment and recovery, instead of using the automatic compensation. A lookup table gives the percentage of constant tension as a function of the total package weight - i.e. how many Niskin bottles are filled with water.
- Prior to deployment, the operator walks through the winch room to inspect system components. At the winch control station, the operator sets a CCTV computer to have unobstructed views of the winch room and operating areas.



R/V Roger Revelle (SIO) – 22 Feb, 2016

During the final stages of deploying a 36-place CTD rosette off the starboard side, the rosette fell from the LARS, resulting in a total loss of the package overboard. Investigation of the incident revealed that the mechanical termination (PMI Evergrip) slipped off, and the secondary cable clamp termination also failed. The termination failure occurred at the final step of the automatic deployment sequence, where the boom is fully extended outboard and the winch holds a constant tension on the wire to hold the package in the docking head. The root cause of the failure is believed to be from the operator’s failure to install the termination as recommended by the manufacturer.

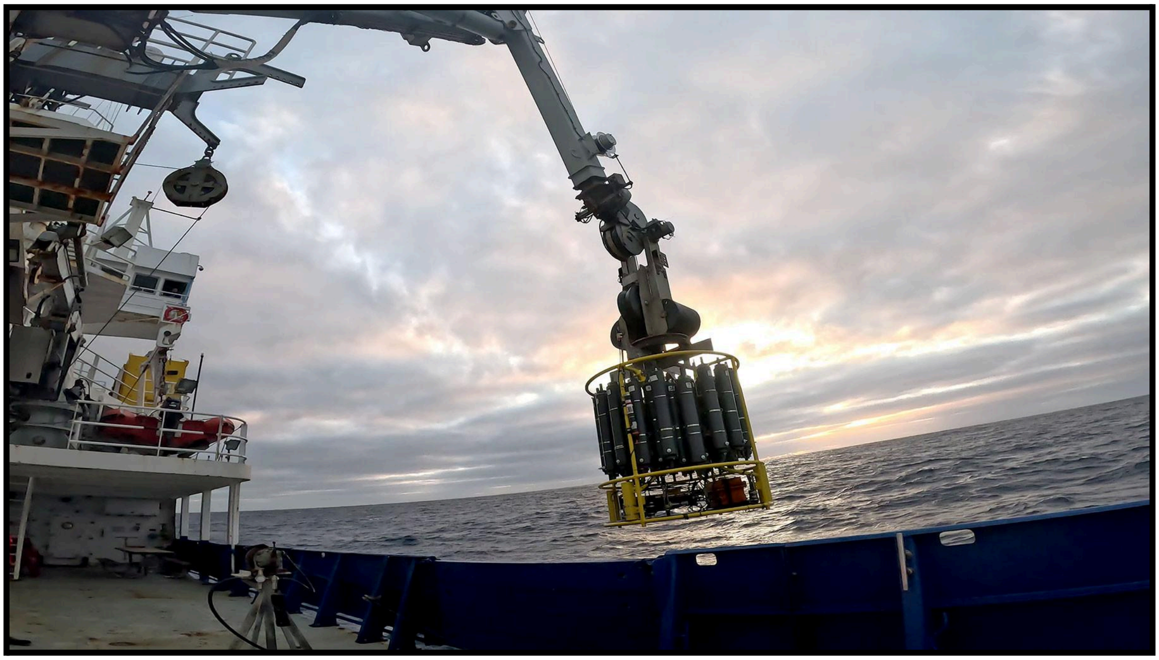


Figure 3 - Revelle’s LARS crane and CTD rosette.

A second, similar incident occurred later on the same cruise with the spare CTD rosette. In this case, the operator controlled the winch manually hauling the package in until it was secured in the docking head. During recovery, the rosette bottles were full of water which increased the weight of the package. Slipping was again observed. Fortunately, the rosette was partially supported by landing on a bulwark, and the termination held up long enough for the rosette to be safely brought back aboard. As in the previous incident, the termination slipped at the end of the launch/recovery sequence, when the maximum tensions were seen on the cable.

Corrective Action:
Termination procedures were reviewed and the process was improved to meet the manufacturer recommendations. No further incidents of this nature have occurred to date on Revelle.

R/V Roger Revelle (SIO) – 2 Feb, 2022

During recovery of a 24-place rosette using the LARS, the 0.322 cable parted and the rosette was lost. The tension monitoring data (see Fig 2) shows that the winch was idle with the rosette at the surface, and then the winch rapidly accelerated until the rosette hit the docking head at a speed of 96 meters/min. The tension quickly increased to over 10,000-lbs (the nominal breaking strength of .322 cable).

As described in the system description above, if the system was being operated correctly, the system should have been in “Auto Mode” and the winch’s speed should have been limited to a speed of 10-15m/min. It is unclear if the system was not actually in Auto-Mode, or if there was a fault in the system that inhibited this safety feature. No faults were identified after the incident during testing, and the LARS has been used extensively with no further incidents of this nature since.

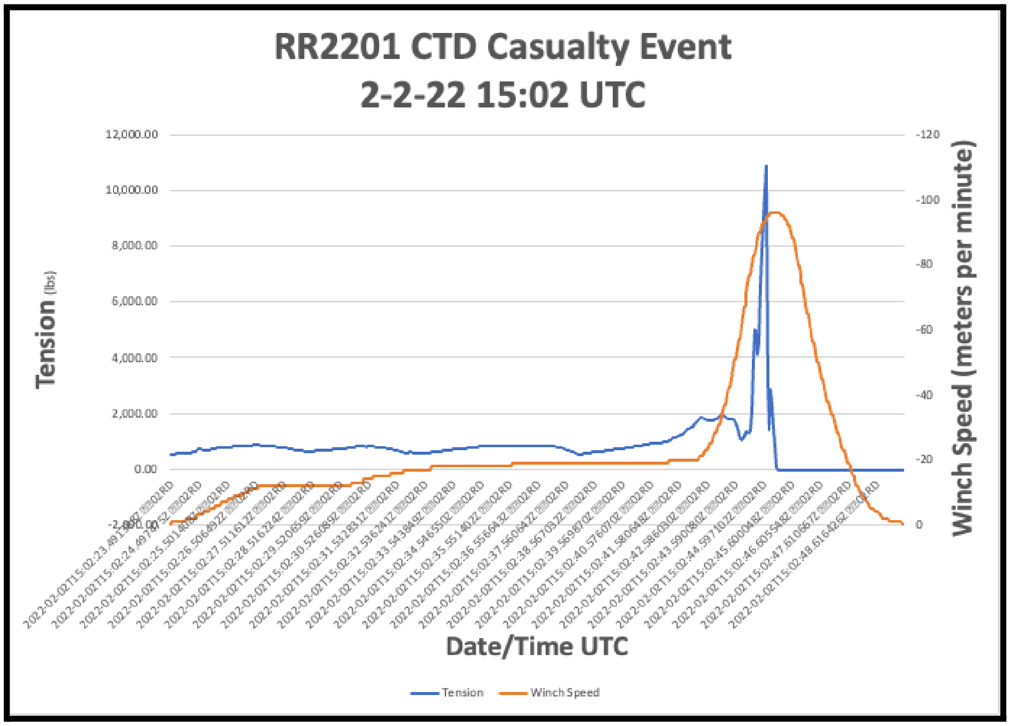


Figure 4 - Winch speed & tension monitoring graph show peaks at the time of the incident.

R/V Neil Armstrong (WHOI) – 9 Dec, 2020

In this incident, the Auto-Mode was activated and the CTD package was lifted and secured in the docking head. However, a faulty proximity switch failed to indicate that the CTD package was properly docked, preventing the system from coupling the winch and boom operations. As the operator extended the handling boom, the winch did not pay out, causing the package to tighten against the docking head and spike the tension. The operator then activated the emergency stop, which reinitialized the system to default Manual mode, where the boom and winch were no longer coupled. Unaware of this change from Auto to Manual mode, the operator continued with deployment, further extending the boom and compressing the docking head springs until the cable parted.

Corrective Action:

The system's Launch/Recovery procedure was updated to require that the package is undocked and re-docked after the system is reinitialized.

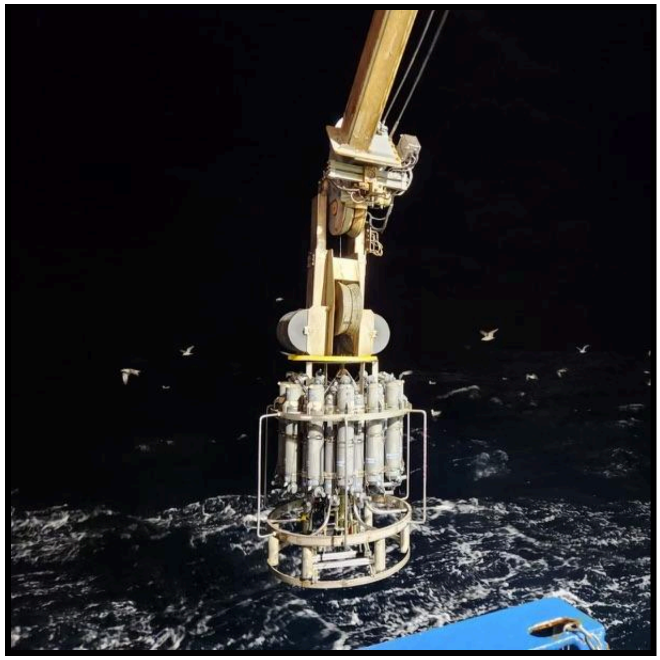


Figure 5 - Armstrong's LARS crane fully extended.

R/V Neil Armstrong (WHOI) – 25 May, 2021

This incident occurred before the docking head proximity sensor could be repaired. Once again, with Auto-Mode activated, the operator manually hauled the CTD rosette until it looked secure in the docking head. At this point, the operator *assumed* the winch operations were coupled to the crane operations as discussed above. The operator extended the CTD handling boom, but the winch did not pay out, so the package compressed the springs in the docking head too much, causing the cable tension to increase until the cable parted.

Corrective Action:

- Systems Interface lowered the system's minimum tension to hold the package in place while the winch controls are coupled to the crane.
- A third layer of proximity switches was added which will shut down hydraulics if the wire tension spikes.
- Operator training revised to state that only one action be performed at a time (ex arm extension, lowering, etc.)

R/V Kilo Moana (UH) – 24 Mar, 2021

This incident occurred during the final commissioning of the Hawboldt system, where two Hawboldt engineers were aboard. One of the main objectives for the team was tuning the winch automation to be more sensitive to crane movements while in "Auto with LARS" mode. This would ultimately minimize an observable jostling/jumping of the CTD rosette as it is lifted and maneuvered within the docking head in "Auto with LARS". During this tuning, while the CTD rosette was being recovered, the rosette dropped 4 feet and then rapidly hauled in, the tension spiked, the cable parted, and the CTD rosette fell to the deck.

It was determined that the failure resulted from a loss of communications between the control system (PLC) and the winch. This breakdown of communication caused the winch to stop moving until it could re-establish communication with the PLC. While the winch was stopped, the crane continued to move inboard causing the CTD rosette to drop ~4 feet. Once communication was re-established (a few seconds later), the system noticed that the CTD rosette was about 4’ out of position and reacted aggressively to bring the package back to where it should be. Unfortunately, the winch hauled in at full speed and the speed of the package impacting the docking head was too fast for the anti-two-block compression sensor to react so the tension spiked and the wire parted. This failure from start to finish happened in about 5 seconds.

Corrective Actions:
UH added safety precautions:

- The winch speed was restricted to 25% of its available speed during launch and recovery in “Auto with LARS” mode.
- The winch speed was restricted to 30% of maximum in manual mode of operation irrespective of payout value. This ensures that an operator cannot haul in on a winch joystick controller and reach a speed that would result in parting the cable should the CTD rosette impact the docking head.
- The proximity sensor was directly wired to the safety relay which enables it to behave as another emergency stop when it is triggered. The response time is much faster than the previous set-up.
- A second proximity sensor was added in parallel with the original to add a layer of redundancy.
- Safeguards were put into place where, If during “Auto with LARS” the winch loses communication, the system automatically switches out of “Auto with LARS”, the winch brake is set, and an alarm sounds. The operator must interact with the alarms and reset the controls in order to continue operations.
- A series of test deployments was added at the start of each cruise to ensure the above points are fully functional.

R/V Kilo Moana (UH) – 23 Jun, 2021

This incident happened during the launch of a CTD, when the CTD package was docked in the docking head and “Auto with LARS” was engaged, the crane and winch exhibited non-standard behavior which was interpreted as a loss of communication between the LARS and the primary controller, a belly pack. At the time of the incident, these control issues had been a recurring problem. Attempts were made to reconnect the wireless belly pack but were ultimately unsuccessful. It was then determined to continue the cast without the belly pack, using manual controls. Unbeknownst to the operator, the system had disengaged the “Auto with LARS” when the belly pack signal was lost. As the operator resumed operations with the crane, the crane movements were *not* followed by automatic winch compensation, a two block occurred, tension spiked and the wire parted.

The user believes that communication between the belly pack and local PLCs was interrupted or lost due to an issue with the receiver module. This receiver module takes the belly pack signal in and communicates with the local console PLC.

After the fact, the operator discovered that the manual hydraulic valve control levers were designed as an emergency bypass and thus all electronic system control fail safes were circumvented when operating from these controls. Procedural changes were made to prevent this sort of cascading failure moving forward.

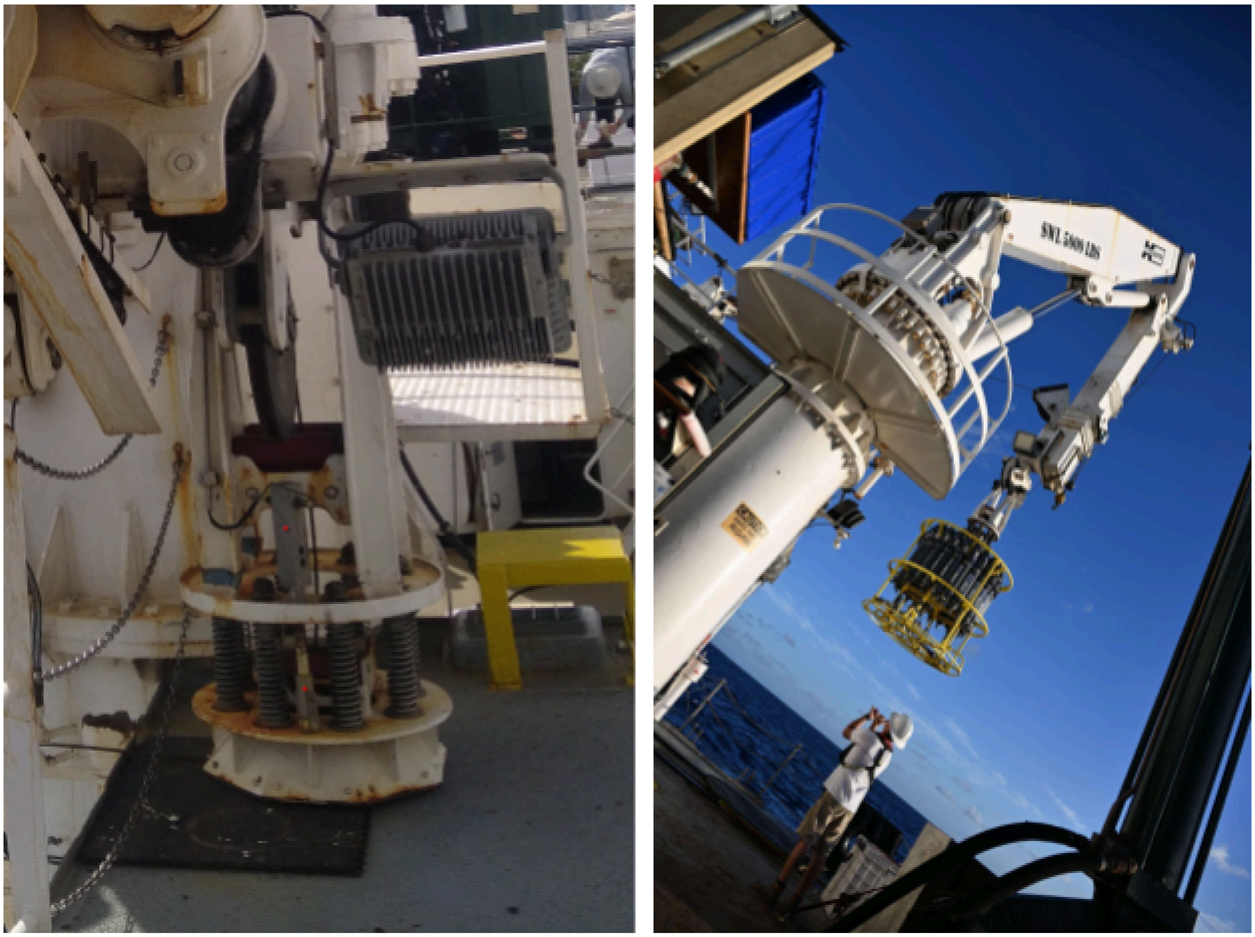


Figure 6 - KILO MOANA docking head (left) and LARS crane partially extended (right)

Corrective Actions:

The crane is never to be operated from the manual hydraulic valve control levers whilst a scientific package is on the end of it and under tension unless the following criteria are met:

1. All belly packs have been deemed unusable by a recognized Hawboldt expert/instructor.
2. The captain, chief mate, chief engineer, and both shipboard technicians have had a meeting to discuss the options/failures.
3. A recognized Hawboldt instructor is operating the controls or directly supervising the operation.

4. The RV Kilo Moana group conducts pre-science safety checks using a test weight and the belly pack controls to make sure the system failsafes are functioning as expected should an inadvertent mode changes occur. These include
    a. Winch Haul in Test - Full speed manual winch haul in full speed into the docking head causing a two block.
    b. Knuckleboom Test - Full speed Knuckle boom deployment in manual, causing a two block.

    In each test the operator monitors and reviews the tension logs to ensure that the system is stopping at the safety set-point.

Summary

While incidents that resulted in the loss of the CTD rosette have occurred for various reasons across the different systems, the failure has always occurred during launch or recovery. Although each system's approach to keeping the CTD rosette (or other package) in the docking head, the LARS systems impart far more tension to the end of the cable during launch and recovery than was seen historically in systems without auto-render winches. In most cases, the highest tensions are seen almost exclusively as the crane moves the docked CTD rosette, and the winch is expected to follow.

Sikuliaq has mitigated some risk by manually setting the upper tension limit in the software on each cast, based on the weight of the CTD rosette. This option may not be practical or available for other systems. Integrated failsafes can also be implemented between the crane and winch by using a series of proximity sensors or a linear transducer to measure the docking head position at finer resolutions, indicating when there is too much compression, and therefore too much tension on the winch cable.

The LARS incidents involved real-time line tension recording systems that control the CTD rosette through automated winch operation. The potential for these systems to overstress the tension member and damage integral components highlights the need to reassess operator interfaces and automation programming as well as look for other possible solutions.

Operators are expected to be aware of when the system is in automatic versus manual modes. As shown in this report, an operator's reliance on these automatic modes to function properly does not necessarily mitigate overall risk to the operation, especially when there are insufficient interlocks or failsafes to prevent incidents from occurring. It is crucial to train operators to understand the default state of the handling system, and to recognize when the system is not functioning as intended. Furthermore, it would be valuable to implement measures that make it obvious to more than just the operator when the system is in automatic mode, such as a signaling light in the deployment area.

Docking heads with mechanical latching mechanisms were identified nearly universally as a potential safeguard. This latch would secure the CTD rosette to the docking head mechanically and avoid the need for high cable tension during launch or recovery. A breakout session was held at the 2021 virtual RVTEC, focusing on existing mechanical latching mechanisms for LARS. Fred Denton from WHOI presented on the ROV Jason's LARS, and Harsen Kocan from MacGregor/Triplex presented on the RCRV LARS, as well as a custom failsafe latching system for docking heads. Hawboldt is in the process of final testing for their latching solution, which can be retrofitted to an existing CTD LARS docking head.

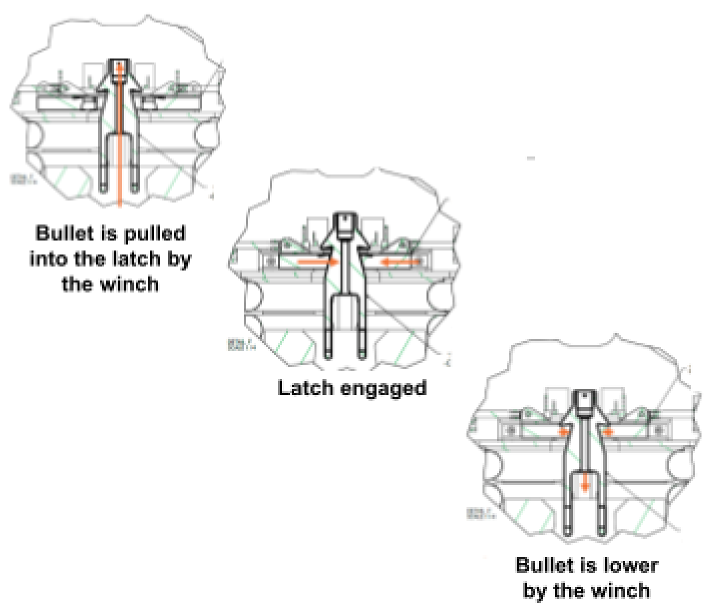


Figure 7. The WHOI/ ROV Jason Mechanical docking head sequence

The ROV Jason's LARS uses a mechanical latching mechanism developed by Woods Hole Oceanographic Institution (WHOI). This system uses a "bullet", as part of the ROV Jason lifting bale, and a mechanical latch on the LARS docking head to secure the ROV Jason into the docking head. The recovery sequence can be seen in Figure 7. (Credit: Fred Denton)

The WHOI ROV Jason team used the following key elements in their system:

- *Air springs in the docking head* provide 4 inches of compliant travel to allow winch to decelerate as torque limiting kicks in.
- *Multiple Latch Indicators* to triple check the latch is holding the load.
- *Transference of the load to the latch* gives winch in tension control mode more time to react to the crane to avoid slack tension and excess tension
- *A Secure Latch Geometry & Counterbalance valve* keep latch closed

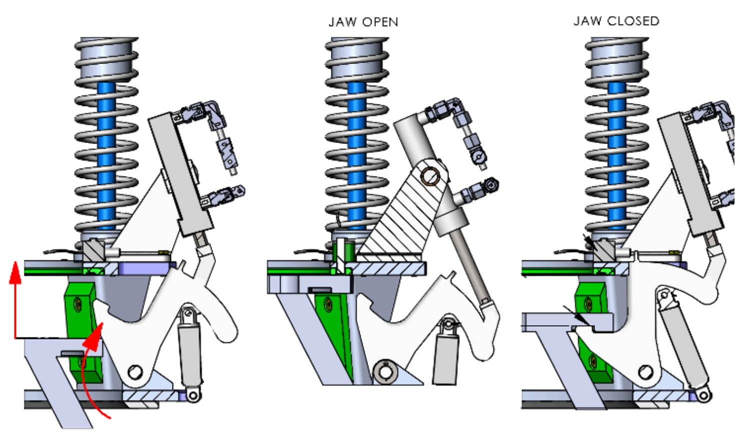


Figure 8 - MacGregor/Triplex docking head with latching system. (Credit: Harsen Kocan)

While this does not eliminate the need for *some* tension applied to the cable, it is much lower than that needed in the current LARS systems. This in turn minimizes the risk of damaging or losing a CTD rosette, as well as improves deck safety. As these LARS are now an integral part of the fleet, it is important that operators continue to communicate about incidents to better improve all operations.

Recommendations

It is recommended that a LARS working group (WG) is established to continue the oversight of the LARS and promote communication about the LARSs within the fleet. This WG could

1. In partnership with manufacturers, conduct a review of current system control algorithms to identify additional possible FAIL-UNSAFE scenarios. From past events it is clear that control systems for automated system must contain interlocks that prevent:
    a. Handling system and winch operation in manual mode when the science package is docked. Docked manipulations require system coordinated control between the crane and the winch.
    b. Any system operations when cable tension exceeds a preset value.
    c. Unintended mode changes (Auto to Manual).
    d. Continued operation of Auto mode when input from critical sensors are missing.
    e. Rapid winch speeds when cable terminations are in proximity to the docking head prior to docking.

2. Establish operational Best Practices such as pre-launch checks on critical sensors.

3. Establish guidance for future equipment specifications that specify minimum required interlocks and a list of failure scenarios to be included during Factory Acceptance Testing.

4. Review risk reduction benefits of latching docking head solutions.

Appendix A

Meeting Participants

Max Cremer	University of Hawaii
Jeff Garrett	U.S. Coast Guard, ret.
Aaron Davis	University of California, San Diego
Paul Mauricio	University of California, San Diego
Amy Simoneau	Woods Hole Oceanographic Institution
Kent Sheasley	Woods Hole Oceanographic Institution
Jim Holik	National Science Foundation
Trevor Young	University of Hawaii
Loren Tuttle	University of Washington
Matt Durham	University of California, San Diego
Tim Deering	University of Delaware
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Brandi Murphy	University National Oceanographic Laboratory System

Working Group Members

Aaron Davis	West Coast Winch Pool
Josh Eaton	East Coast Winch Pool
Mike Einhorn	Einhorn Engineering
Matt Durham	University of California, San Diego
Lance Frymire	University of Hawaii
Ethan Roth	University of Alaska, Fairbanks
Alice Doyle	University National Oceanographic Laboratory System