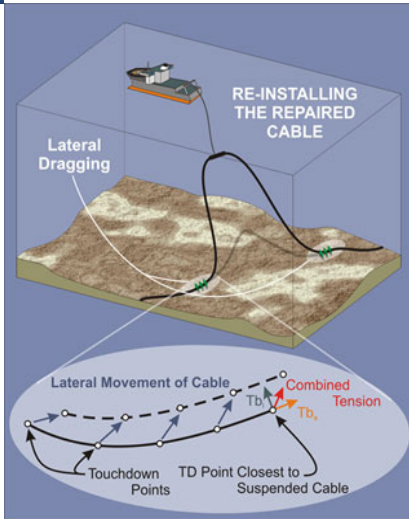
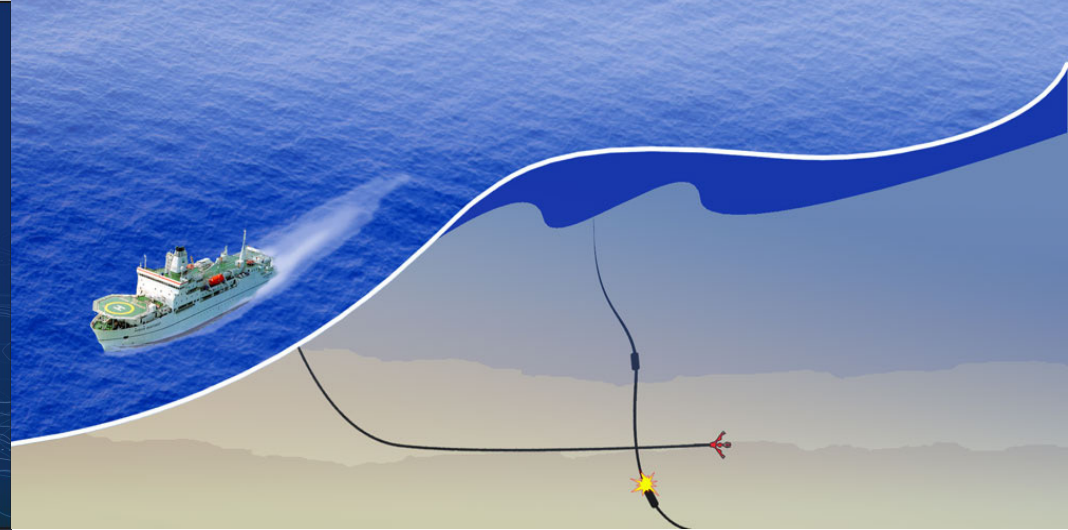


MakaiRepair

Submarine Cable Repair Management Software



INTRODUCTION

MakaiRepair extends the capability of Makai's industry-standard submarine cable planning and installation software suite to include at-sea cable repair and recovery operations. It is a standalone product that runs on a standard PC operating with Microsoft Windows 7 or XP and which is installed on a repair vessel. The software is available in a standard or professional version depending upon client needs.

MakaiRepair includes new grapnel/assembly tools and modifications to the advanced 3D finite element model that takes into consideration multiple cables in the water column and lateral movement of the cable along the seafloor. These new features to the cable model allow for the precise control of bottom tension, so that the recovery of the cable can be done at faster rates, within safe parameters, thereby speeding up operations and minimizing repair operational costs.



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AT-SEA REPAIR AND RECOVERY OPERATIONS

In addition to sharing a large number of features already existing in MakaiLay (see Makai's brochure on MakaiLay for details) both the Standard and Pro versions of MakaiRepair have the following capabilities for at-sea repair and recovery operations:



FEATURES COMMON TO MAKAIREPAIR STANDARD AND PRO	
1) Familiar user environment	
	a. GIS environment capable of importing all types of georeferenced data such as bathymetry, bottom slopes, nautical charts, soil types, and paths of existing cables
	b. Shared graphical user interface (GUI) with Makai's cable route planning (MakaiPlan) and installation (MakaiLay) software to lighten the training burden and provide a common framework for planners, installers and repair personal
	c. Seamless exchange of cable route, cable assemblies and as-laid cable routes created using other Makai software products
2) Create, edit and display ship plans involving multiple cable engines	
	a. Generate, edit and display preliminary ship plans for each phase of a repair operation including grappling runs and cable recoveries
	b. Customize views to display relevant data to multiple operators on the repair vessel such as the helmsman display and cable engine display
3) Data and event logging	
	a. Receive, log, and filter navigation data and measurements from multiple cable engines simultaneously
	b. Log events which occur during repair operations in a database for easy reporting and archiving
4) Tools for repair planning and operations	
	a. Buoy selection tool to operate effectively in ocean currents, at user-specified water depths and with user defined cable assembly
	b. Grapnel design tool to estimate the length of rope required to ensure proper touchdown of the grapnel assembly in user-specified conditions
	c. Steady-state calculator of the cable shape, position and tension for planning and monitoring repair operations

The Professional version of MakaiRepair contains all the capabilities of the Standard version plus advanced real-time modeling and control capabilities. What MakaiLay does for installations, the MakaiRepair Pro version does for repairs and recoveries. These advanced capabilities are recommended for situations which necessitate the accurate monitoring and control such as the rapid recovery of an already laid cable, or operations in congested waters where accurate placement is a priority. Use of MakaiRepair Pro provides operators with the following advantages:

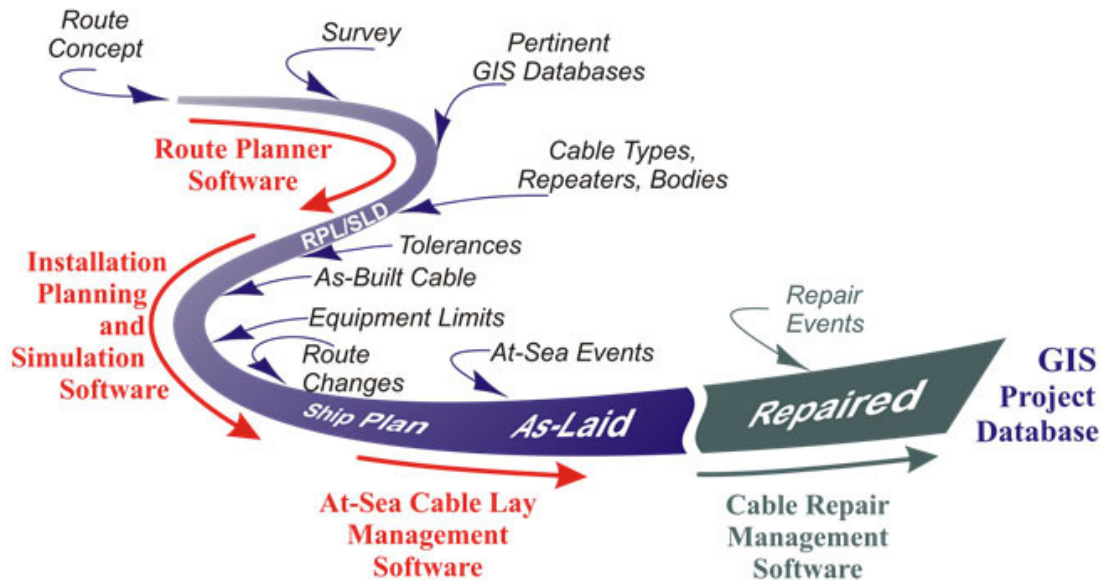
MAKAIREPAIR PRO FEATURES	
1) Real-time monitoring	
	a. The 3D, hydrodynamic cable model calculates solutions in real-time during different phases of the cable repair process
	b. Critical outputs such as the bottom and top cable tension, amount of cable dragged, and the shape of the cable in the water column and seabed are displayed to alert the user of potential issues
2) Feed-forward control	
	a. Because the cable model converges faster than real-time, users can use it to accurately predict how a given set of instructions will affect seabed cable tension and position in the near future
	b. Instructions can be generated at-sea "on-the-fly" and displayed to the helmsmen and cable engine operators
	c. Results in improved recovery techniques to reduce cable tensions and decrease risks associated with repair operations such as high cable tension or cable dragging
3) Faster cable retrieval	
	a. By accurately modeling the cable tension and shape, operators can recover cable significantly faster than can be achieved using conventional methods
	b. Recovering cable faster reduces costs associated with ship time at-sea

FEATURES COMMON TO MAKAIREPAIR STANDARD AND PRO

FAMILIAR USER ENVIRONMENT

MakaiRepair shares the same graphical user interface (GUI) as MakaiPlan and MakaiLay, the submarine planning and at-sea installation software products. This provides a familiar feel for route planners, at-sea installers, repair operators and project managers yielding a common basis for thinking about, planning, and executing operations. Users experienced with MakaiLay can step right in and use MakaiRepair with little training.

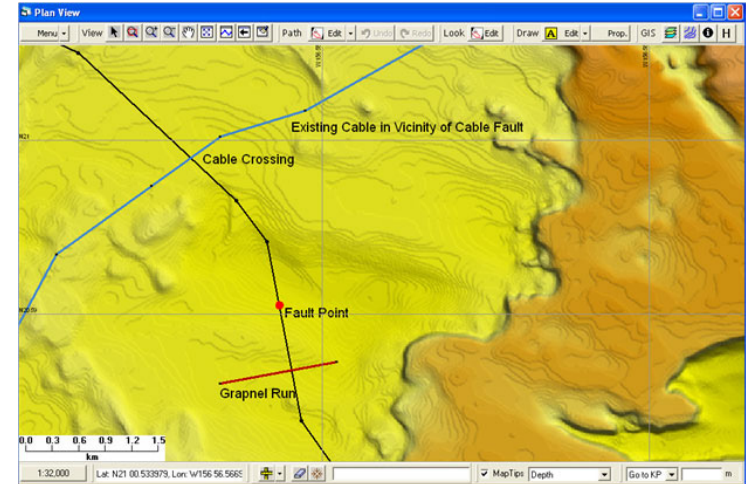
As with Makai's other cable software products, MakaiRepair provides a GIS environment capable of importing and manipulating a wide variety of georeferenced data including bathymetry, bottom slopes, nautical charts, annotations, restricted areas, soil types, and paths of existing cables in the region. All this information is viewable on a single display, so operators can make informed decisions without consulting multiple sources of information.



MakaiRepair is an extension of the GIS project database used in planning, simulating and installing submarine cables.



Makai Research Pier



Screenshot of MakaiRepair showing grapnel run next to fault location of cable. Other GIS information, such as bathymetry, existing cables in the vicinity, and marine hazards, can also be displayed.

Planned and as-laid cable routes generated in Makai's other software products can be seamlessly integrated into MakaiRepair. If a cable was installed using MakaiLay, the resulting as-laid path can be imported into MakaiRepair, annotated to note the approximate location of the fault, and used to plan and execute the repair operation. If using MakaiRepair Pro, the resulting as-laid path of the repaired cable can be updated and loaded back into the project database.

FEATURES COMMON TO MAKAIREPAIR STANDARD AND PRO CON'T

CREATE, EDIT, AND DISPLAY SHIP PLANS INVOLVING MULTIPLE CABLE ENGINES

Ship plans including navigation waypoints and cable payout instructions for multiple cable engines can be created and modified using the tools in MakaiRepair. Using the same procedure as used in MakaiLay, operators can generate ship plans based on cable and grapnel paths. Unique to MakaiRepair is the ability to have multiple grapnel paths (which define planned grappling routes) associated with a single grapnel assembly,

Unlike standard cable laying operations, repair operations can involve the use of multiple cable engines simultaneously. This capability is useful when one section of the cable is being installed and the other is being retrieved prior to repairing the cable with a splice. The waypoints of the ship can be changed “on-the-fly” to account for ocean currents or surface obstacles such as other ships which need to be navigated around. Using the same communication software utilized by MakaiLay, these ship plans together with other relevant information (e.g., nautical charts) can be displayed directly to the helmsman and cable engine handlers, or any other client computers located on the vessel.

DATA AND EVENT LOGGING

All data critical to repair operations are logged by MakaiRepair including time-tagged navigational and cable engine data. As mentioned previously, MakaiRepair has the capability to receive, log, and filter data from multiple cable engines and this data can be displayed, corrected, and exported using the same charting and query utilities of MakaiLay.

MakaiRepair also contains a customizable database to log events during repair operations. All events in the database are time-tagged and categorized to facilitate rapid searching while at-sea or reporting once the repair has been completed.



TOOLS FOR REPAIR PLANNING AND OPERATIONS

MakaiRepair includes several tools to assist operators to make fast decisions before and during the operation. Some of these tools include: (1) a tool to calculate the required grapnel rope length for user-defined grapnel assembly or a desired grapnel bottom tension (it takes into account the user-specified water depth and ship speed and estimates the length of grapnel rope required to ensure proper touchdown of the grapnel while grappling); (2) a buoy selection tool that takes into account the user-specified buoy assembly and expected ocean currents. Using the results of these tools allows an operator to create an assembly appropriate for any operation which can be printed in schematic form for easy rigging. Central databases including all the grapnel and buoy assemblies can also be created to facilitate their rapid inclusion in future projects.

Screenshot of the grapnel rope length tool.

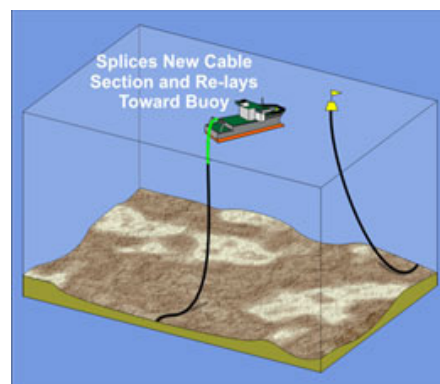
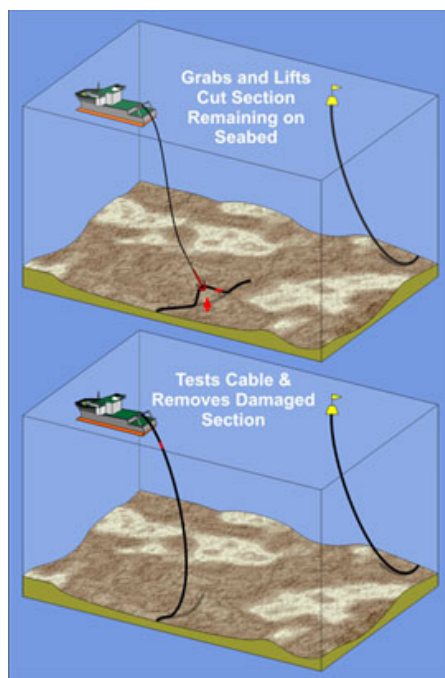
The Standard version of the software also includes a cable model which calculates the steady state shape, position, and tension distribution of cables and grapnel assemblies during repair operations. This model uses the properties of the cable and grapnel assembly components (i.e., cable types, diameters, wet weights, drag coefficients, inline bodies) and can be used to estimate where a grapnel is located and when it can be expected to intersect with the cable being repaired.

MAKAIREPAIR PROFESSIONAL FEATURES

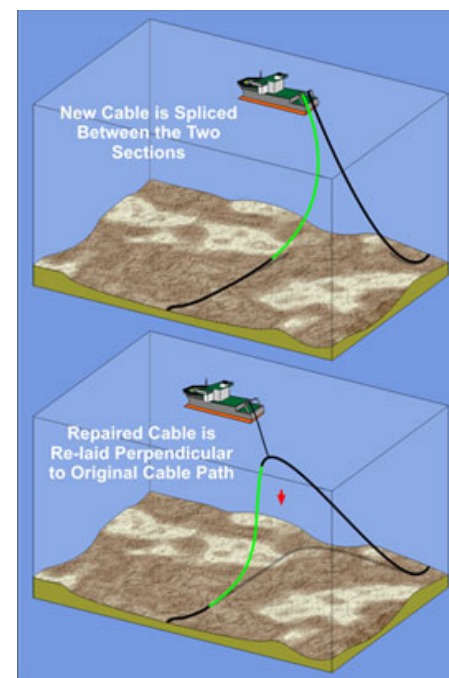
The Professional version of MakaiRepair includes a real-time, 3D hydrodynamic model to accurately monitor and control each phase of a repair operation. Multiple benefits are provided by using the cable model at-sea such as mitigating risk (such as breaking the cable or damaging it by excessive dragging along the seafloor) due to operator error and significantly increasing the safe recovery rate of cables.

REAL-TIME MONITORING

Unlike conventional cable lays, multiple cables can be in the water column and connected to the vessel simultaneously during a repair operation. The cable model used by MakaiRepair is an expanded and enhanced version of the same validated cable model used by MakaiLay which allows for the real-time modeling of multiple cables simultaneously. It takes as input, the cable and body properties, bathymetry, as-laid paths, navigation, and cable engine data to calculate the seabed cable position and tension. It is capable of modeling all phases of a repair operation including grappling operations, retrieval, buoying, simultaneous installation and recovery, splicing, and re-installing the repaired cable. Using the model as a monitoring tool provides operators with real-time knowledge of the shape of the involved cables between the ship and the seabed, as well as a reliable record of touchdown positions. Charts are available to display the calculated tension of the array at the bottom as well as the distance the cable has dragged.

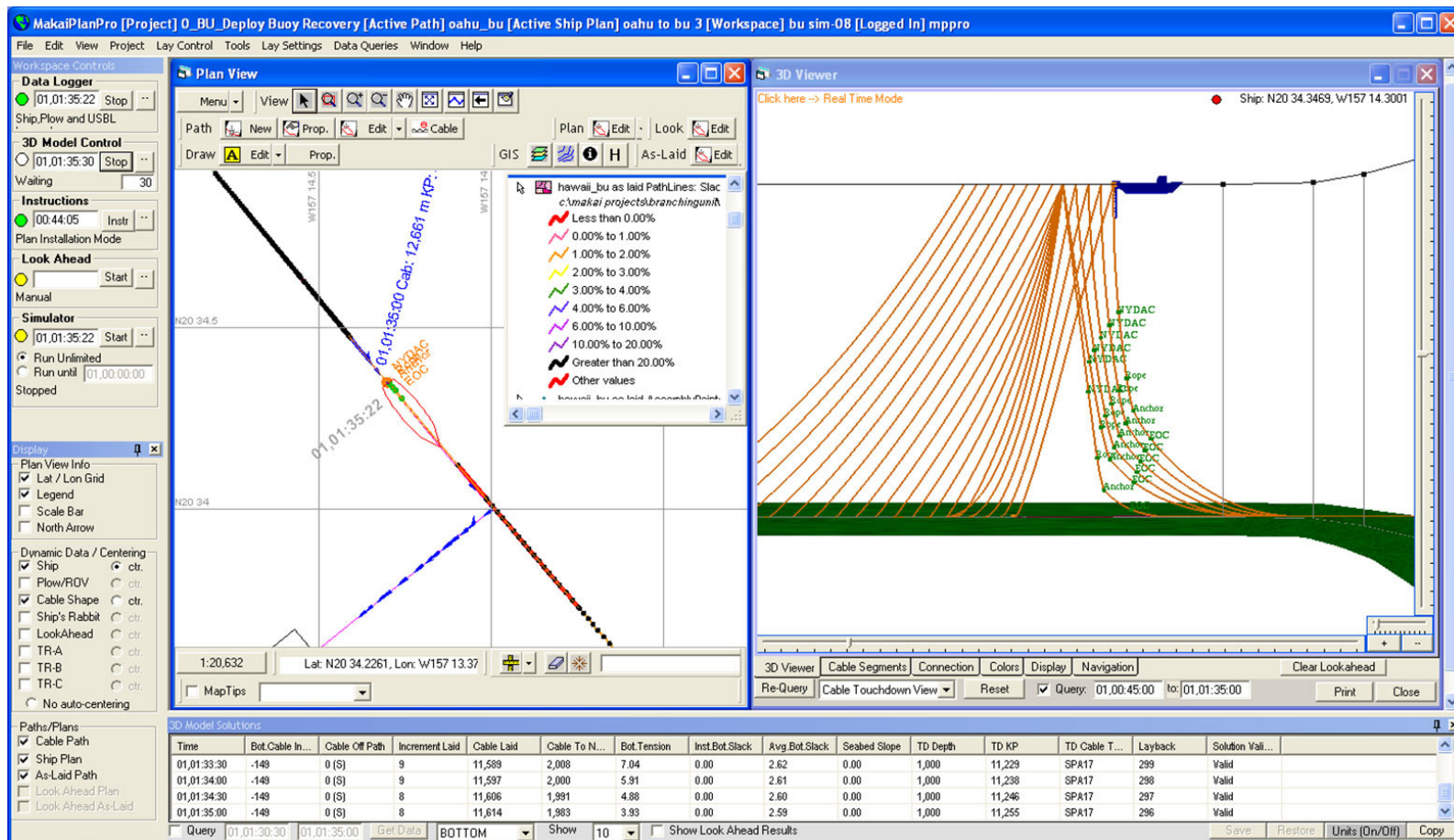


MakaiRepair Pro is capable of modeling all phases of a repair operation including grappling operations, retrieval, buoying, simultaneous installation and recovery, splicing, and re-installing the repaired cable.



FEED-FORWARD CONTROL TO REDUCE RISK

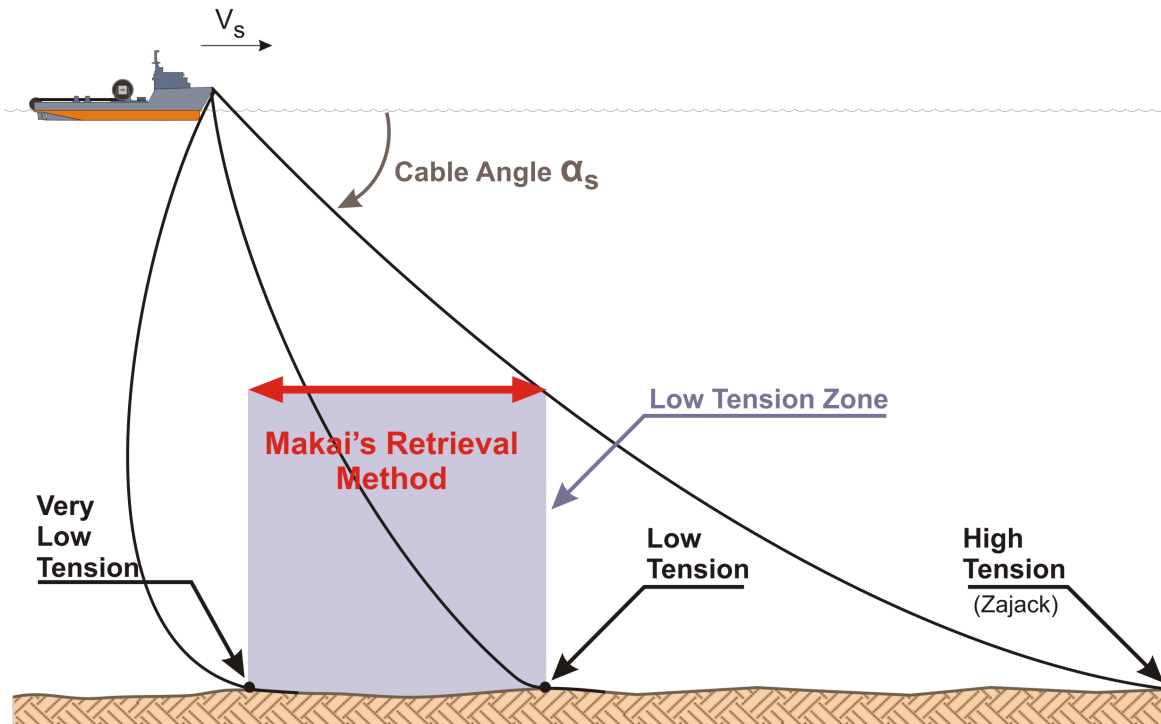
Because the model is optimized for repair and recovery operations, it converges significantly faster than real-time. Consequently the operator can accurately predict how a given set of instructions will affect the cable tension and position (e.g., cause the cable to drag across a rock outcrop or induce dangerously high tensions) before it actually happens. This capability allows the software to be used as a feed-forward control tool to generate “on-the-fly” instructions to reduce risk and safely install and/or recover multiple cables simultaneously. During unplanned contingency situations, the results of the tool can be used to inform operators as they make rapid decisions to preserve operator safety and prevent further damage to the cable.



MakaiRepair Pro uses a 3D finite segment model that has been optimized for repair operations. The model differs from the standard MakaiLay model in that it takes into consideration multiple cables in the water column and cable dragging on the seafloor.

FASTER CABLE RETRIEVAL

Maintaining a desired working load of tension during retrievals is crucial to: 1) maintain safe working conditions which mitigate the risk of cable breakage; 2) prevent damaging the cable by excessively dragging it along the seabed; and 3) ensure that cable is not being retrieved at zero tension in which case it will loop around any bottom outcrops present. Conventional methods of cable retrieval are based on steady state approximations and do not provide repair operators with an accurate understanding of, or control over, the cable tension at the seabed. Consequently, repair operations are conducted at slow speeds (typically less than 1 knot) and with a low top angle (around 60 deg) to ensure that they maintain desired bottom tension. This can become costly when retrieving substantial lengths of cable.



MakaiRepair Pro allows engineers to increase the rate of cable recovery and payout while operating in low to very low bottom tension.

	Retrieval Rate (knots)	Top Tension (kN)	Bottom Tension (kN)
MakaiRepair Pro ($\alpha_s = 120^\circ$)	2.0	29	21
Conventional ($\alpha_s = 60^\circ$)	1.1	29	21
Conventional ($\alpha_s = 60^\circ$)	2.0	52	44

MakaiRepair Pro can drastically increase the rate of cable recovery and re-lay while maintaining safe bottom tension values.

By using the MakaiRepair Pro cable model, a repair operator can accurately monitor the bottom tension and can consequently recover cable at a much faster rate with confidence. As shown in the table above, for a given bottom tension of 21 kN, the cable retrieval rate can be doubled which directly reduces the cost associated with ship time at sea.