Helicopter Rappel -
Equipment Testing and Evaluation

Submitted to:
Yosemite National Park

Date(s) of Testing/Evaluation:
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Submitted by:
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Introduction:

Rigging for Rescue, LLC, in conjunction with Yosemite National Park Service (NPS) all-hazard personnel, conducted three days of drop testing and systems analysis on helicopter rappel equipment and scenarios. The testing was completed at the Yosemite National Park Crane Flat Helibase utilizing the Helibase rappel tower. The drop testing incorporated the use of live rappellers (in a belayed capacity) as well as an articulating mannequin combined with steel weights (aka Rescue Randy).

Background:

The 'legacy system' that has been utilized by both the NPS and the US Forest Service for helicopter rappel operations includes a ½ inch Nylon 12-strand braided rope in combination with a Sky Genie descent control device manufactured by Descent Control, Inc. The legacy system has been in service for many years and has been safely employed in thousands of helicopter rappels. The intent of the October 28-30, 2010 test series was to critically examine newer, modern equipment options for helicopter rappelling as potential replacements or alternatives to the legacy system.

Objectives:

In addition to subjective equipment evaluation in a helicopter rappelling capacity, the test series focused on objective evaluation of specific scenarios that were expected to produce high maximum arrest forces.

Namely:

- a fall/slip by the rappeller out of the aircraft while near the edge of the open door (e.g. loss of balance due to a change in orientation of the aircraft)
- a rapid descent followed by a sudden stop (e.g. allowing a mechanical device to initiate a rapid stop or rappelling quickly into a knotted rope)

Various combinations of newer, modern equipment were examined as well as the legacy system for comparative purposes. Maximum arrest forces were captured using an electronic load cell.

The test set-up(s) were intentionally severe in their nature in order to provide meaningful data and direction on the question:

“In the above scenarios, are the peak forces being transmitted to the anchor system in the aircraft too high given the combination(s) of the newer, modern devices and ropes?”

Equipment Selection and Criteria:

A total of three descent control devices (DCD) and four rope types were selected for examination. The DCDs chosen were the Petzl RIG, the SMC Spider and the Sky Genie. The rope types were the Petzl Vector, PMI EZ Bend, Bluewater Dynastat and the braided nylon rope from the legacy system.

The criteria for DCD selection included the following:

- general size, weight and profile of the device
- ergonomics of the design (e.g. handle position and curvature; use with gloved hands)
- bandwidth of rope diameter accepted
- ability to ‘stack’ multiple devices on the rope in order to facilitate rapid rappel transitions
- ability to rig/derig the rope from the device without removing it from the attachment point carabiner (this is a speed factor while de-rigging a device at the end of a rappel in order to disconnect from the line going to the aircraft; additionally, it prevents dropped devices)
- ease of loading the rope (i.e. presence of appropriate icons, intuitive design)
- ease of inspection
- ease of use (dexterity required)
- presence of a incorrect loading fail-safe
- presence of a ‘deadman’ feature (aka ‘hands free stop’- an automatic stop initiated by the device if the rappeller were to let go of the DCD)
- presence of a ‘panic stop’ feature (a camming effect on a mechanical device whereby the device locks up and/or inhibits/stops rope travel should the operator open the cam too widely in a panic reaction)
- presence of third party certifications and/or classifications (e.g. CE, NFPA, UL, ANSI)

Petzl RIG

SMC Spider

Descent Control Inc. Sky Genie

The criteria for rope selection included the following:

- elongation
- diameter
- breaking strength
- construction
- fiber content
- suppleness
- presence of a sewn termination attachment point

Test Method:

Two scenarios were examined in the test series:

Scenario 1: a fall/slip by the rappeller out of the aircraft while near the edge of the open door
Scenario 2: a rapid rappel followed by a sudden stop

Additionally, within the context of each of those two independent examinations, we utilized two test set-ups per scenario:

- Scenario 1 tests were conducted with a single DCD on the rope as well as 'stacked' DCDs

- Scenario 2 tests were conducted using live rappellers as well as Rescue Randy.

Scenario 1 Test Design

This test was intended to replicate a rappeller falling out of the aircraft while near the door opening due to a slip or a change in orientation of the aircraft. The resulting fall would produce a shock force on to the rappel system.

To replicate a representative amount of rope-in-service at the time of the event, the following steps were followed:

1. the spotter anchored the rappel rope to the overhead anchor point in the aircraft
2. the spotter re-directed that rope through the change-of-direction carabiner anchored above the door opening
3. the spotter pulled up slack rope from below the re-direction point and handed a bight of that rope to the rappeller seated in the first position nearest the door
4. the rappeller reeved the rope into the DCD, pulled the running end of the rope hand tight and secured the DCD
5. the spotter made their system inspections and gave the agreed upon 'OK' signal to the rappeller

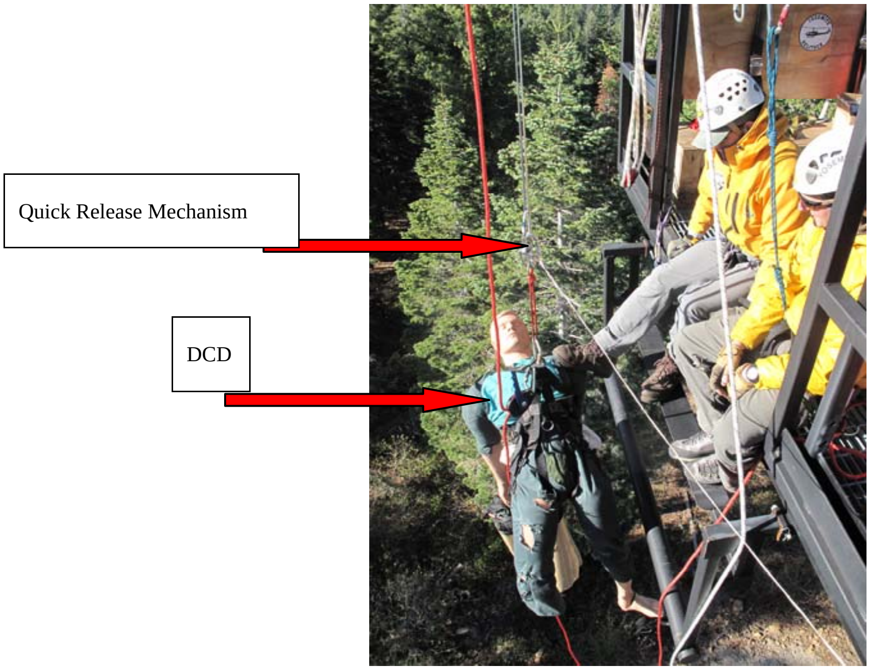
Rappeller loading a DCD

At this point in the test design, we then measured how much rope was in-service between the DCD and the primary anchor point in the aircraft. The amount of rope was 5 ½ feet.

To replicate a representative amount of slack in the system prior to the rappeller falling out of the aircraft the following steps were used:

1. the rappeller stood up from their seated position and made their way to the door exit
2. the rappeller stopped at the door opening just prior to grabbing the pre-rigged handle (an anchored Figure of 8 plate which is standard procedure in the legacy program)
3. the rappeller did not take in any slack rope through their DCD during this maneuver
4. a linear measurement was then taken of the distance between the DCD attached to the rappeller and the primary anchor point. This distance was 5 feet.

As a result of this test design methodology, a drop test using an articulating mannequin of ½ foot freefall on 5 ½ feet of rope would have been sufficient to accurately represent a slip/fall out of the aircraft. However, because certain mechanical devices allow some rope to 'slip' or travel through the device when not under tension (e.g. while approaching the door; aka 'untensioned slip') it was felt by the examiners that the amount of slack rope should be increased to 1 foot. This increased amount of freefall would produce a greater peak force on the system.

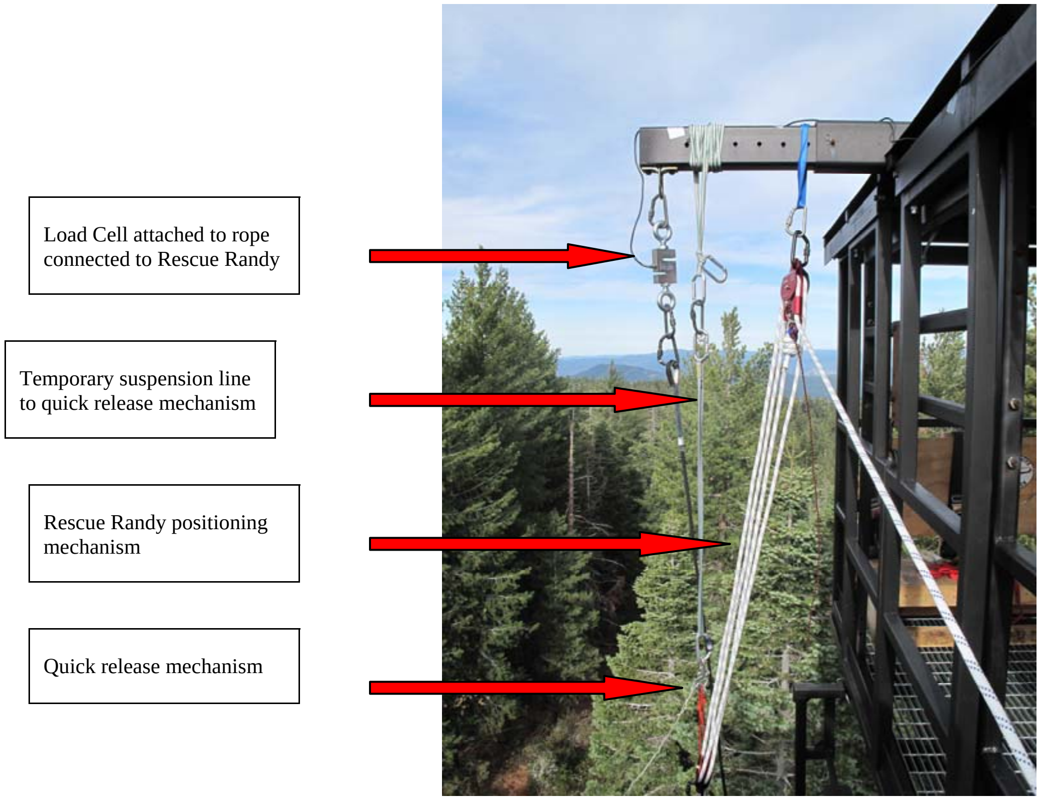


Rescue Randy in position for a drop

As stated above in the Objectives section, the test design was intentionally skewed to be slightly more severe that you would expect in a real scenario in order to help answer the question: "Are the peak forces being transmitted to the anchor system in the aircraft too high given the combination(s) of the newer, modern devices and ropes?" If the recorded forces were at acceptable levels using this test design, then a presumption could be made that they would be at acceptable levels in less severe circumstances.

All drop tests conducted in Scenario 1 employed the use of Rescue Randy and steel weights. The total test mass was 300 lbs. – the maximum allowable rappeller weight as indicated by the Interagency Helicopter Rappel Guide. Rescue Randy was 184 lbs. and the steel weights (and backpack) were 116 lbs.

All tests were conducted using a cantilevered beam off of the drop tower. This enabled us to drop the test mass in a freefall without risking Rescue Randy's legs becoming entangled in the skids. Any striking of the skids would have reduced peak forces transmitted to the primary anchor point in the aircraft. Our objective in the test design was to make it an intentionally severe examination with respect to the forces created by a fall out of the aircraft.



Scenario 1 test set-up

During the test series, all of the DCDs were brand-new save for the legacy system device (Sky Genie). Because the same DCDs were used on multiple drop tests, they were only brand-new on their initial drop test.

Multiple rope types were used in the test series. The ropes consisted of brand-new, new with limited use and older used rope (the legacy system rope). Additionally, rope ends were swapped between drop tests for a given rope sample. For example, a drop test would be conducted on Rope X; the next drop test would often use the very same rope, but the ends would be switched – hence the terms in the drop testing log sheets (Appendix A) of “Side A” and “Side B”. Switching the rope ends between drop tests allowed for some relaxation time of the shock-loaded rope. Subsequent drop tests on that partially relaxed rope would typically produce higher peak forces, as expected. The test series was conducted this way as a result of limited rope resources readily available for examination.

A quick-release mechanism was incorporated into the test mass suspension system. For a given drop test, the test mass was quick-released on to the DCD and rope combination; forces were measured by an electronic load cell set at 2400 Hz.

Scenario 2 Test Design

This test was intended to replicate a rappeller in a rapid descent coming to a sudden stop. Tests were conducted using Rescue Randy as well as live rappellers. The speed of the rappels was not measured and it appeared to be highly variable.

Live rappellers were instructed to rappel "fast" and then let go of the DCD release mechanism upon reaching a visual marker attached to the rappel tower. The live rappellers were belayed with a separate rope. Force measurement was taken with an electronic dynamometer as opposed to a load cell. The initial tests using a load cell and live rappellers had such small recorded forces that it was difficult to discern the peak force from the normal oscillations in the force/time curve.

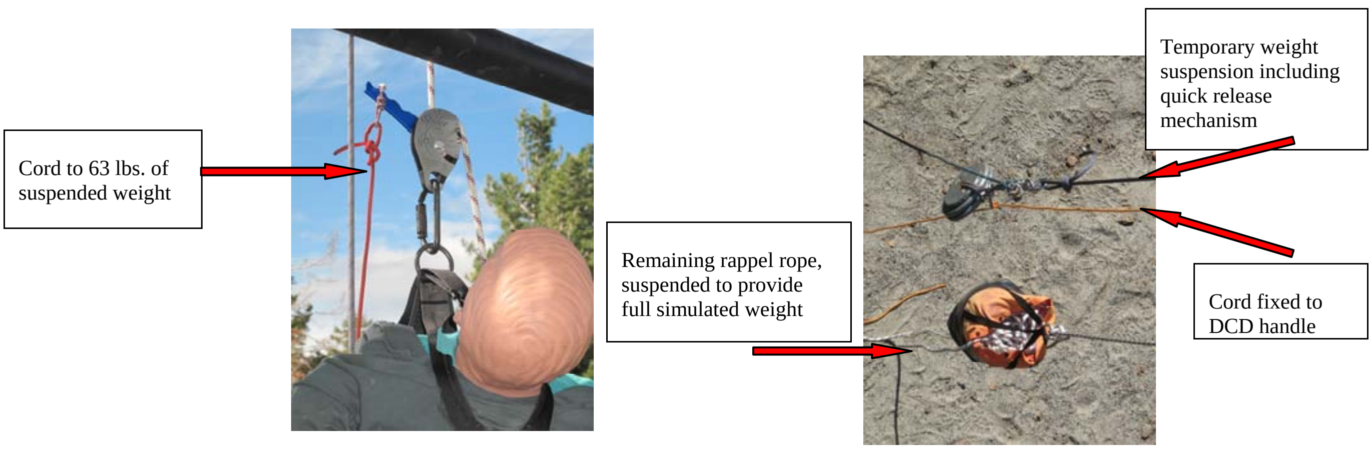
Spotter briefing the rappellers

Rappeller on skid prior to rapid descent

The test set-up using Rescue Randy as a rapid rappeller was a difficult-to-replicate challenge. To replicate an out-of-control rappeller followed by a sudden stop, the following steps were used:

1. Rescue Randy was positioned on rope just below the skids – approximately 50 feet above the ground.
2. An attachment loop was fixed to the end of the DCD handle (SMC Spider). A long extension came off of that attachment loop - towards the ground – and was connected to a stack of independently suspended weights (63 lbs.; enough weight to smoothly initiate the DCD cam).
3. The independent-weights suspension system incorporated a quick-release mechanism to transfer the 63 lbs. of weight on to the DCD handle attachment loop, thereby initiating an out-of-control rappel. The 63 lbs. of weight were initially suspended approximately 6 feet off of the ground.
4. When the weights contacted the ground - after 6 feet of travel – the force on the DCD handle would cease and the DCD cam would engage and initiate a sudden stop.

On the Rescue Randy tests, forces were measured by an electronic load cell set at 2400 Hz.



Scenario 2 Rescue Randy test set-up

Results and Discussion:

On October 28-29, 2010, a total of 38 tests were conducted and recorded at the Yosemite National Park Crane Flat Helibase utilizing the Helibase rappel tower. A total of 31 tests involved the use of Rescue Randy as the test mass; an additional 7 tests employed live rappellers in a 'sudden stop' scenario.

Additional rappel system evaluations were conducted on the afternoon of October 29, 2010, utilizing live rappellers, but no force measurements were recorded – the forces were benign as they did not involve a 'sudden stop' simulation. The additional rappels were used to evaluate ropes and DCDs against objective/subjective criteria. The live rappellers subsequently completed evaluation forms (Appendix C) during the October 30, 2010, testing debrief and discussion.

The summary statistics are limited to drop tests #1-28, which involved testing to Scenario 1 parameters. The drop tests simulating a 'sudden stop' (Scenario 2) were of a limited quantity and qualify only as a 'quick look' from a testing standpoint.

The results and discussion are categorized by DCD and rope.

DCD

A total of three DCDs were examined in the drop test series:

- Petzl RIG
- SMC Spider
- Descent Control Sky Genie

Several other DCDs were considered, but they were eliminated in preliminary discussions for a variety of reasons specific to each device. The DCDs considered included:

- Petzl I'D
- Black Diamond ATC Guide
- Edelrid Eddy
- Petzl Grigri
- Heightec PMI-Powerlock

The vast majority of the drop tests were conducted on either the Petzl RIG or the SMC Spider. Of the available choices, these two DCDs were deemed to have the most promising overall mix of qualities as they pertain to a helicopter rappelling application.

The Sky Genie was tested only twice in order to obtain 'quick look' comparative data points. Additionally, the drop test parameters for the Sky Genie were modified slightly in order to account for the longer profile of the device.

The overall data summary is as follows:

Summary Data

	DCDs		
Force (lbF)	**Petzl RIG**	**SMC Spider**	**Sky Genie**
Minimum	1214	1215	1274
Maximum	1502	1673	1422
Average	1378	1480	1348

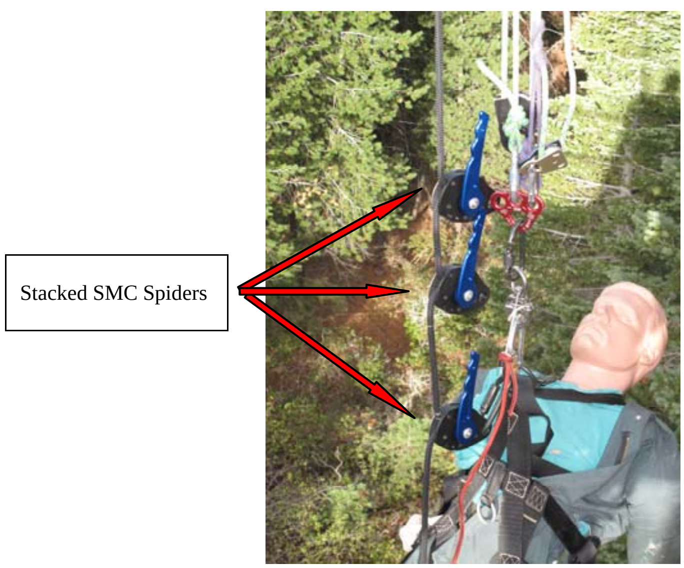
The overall range of forces recorded for each device was similar. This was to be expected as there was very little observable slippage of rope through either device during the test series. It is likely that the overall range of forces recorded were almost exclusively attributable to the different rope types and their elongation qualities.

Additionally, the forces recorded were below commonly-referenced (e.g. OSHA) maximum allowable arrest force values for an adult in a full body harness.

‘Stacked’ Devices

In helicopter rappel operations using the legacy system, stacking devices (pre-rigging them on the rappel line – 3 in total to start) is a commonly utilized practice. Accordingly, it was an objective of this test series to determine if newer, cam-controlled devices could also be ‘stacked’. Notable performance differences were observed between the Petzl RIG and the SMC Spider when examined in a ‘stacked’ configuration.

Each of the two DCDs were tested in a manner similar to drop tests # 1-20 with the exception that two additional DCDs were ‘stacked’ on the test rope (tests #21-28). This test set-up made it difficult to determine the *fall factor* for each drop. Additional rope (more than the prescribed 5 ½ feet) was required to position Rescue Randy because of the reeving of rope through two additional devices. However, that extra rope was not providing an equivalent elongation quality because it was captured in a cammed device. As a result, we chose to ignore an actual fall factor calculation for the ‘stacked’ drop tests. In addition, fall factor in this scenario is largely irrelevant, as the original freefall of 1 foot, as prescribed by the test set-up parameters, was still maintained for each of the tests. The accompanying photo illustrates the test set-up.



Stacked drop test set-up

The SMC Spider performed satisfactorily in a ‘stacked’ configuration. There was no visible damage to any of the DCDs or to the ropes examined. Additionally, the SMC Spider does not require (for security) a carabiner to be affixed to the device while in a ‘stacked’ configuration.

The PETZL RIG is not a suitable device in a ‘stacked’ configuration as evidenced by drop test #21. During this test, the two ‘stacked’ Petzl RIGs were both severely damaged (yielded) and no longer usable.

Stacked Petzl RIG damage

It is yet to be determined whether ‘stacking’ cam-controlled devices is a suitable practice in helicopter rappel operations. The spotter used in the test series was a very experienced practitioner; he expressed that it was prohibitively difficult to manipulate ‘stacked’ devices along a weighted rope. Although our test series briefly examined the ‘stackability’ of the SMC Spider and Petzl Rig, it is not within the scope of this report to determine whether ‘stacking’ is a practical helicopter rappel practice.

Other DCD Criteria

In addition to the empirical data on the two DCDs examined, a number of other criteria were evaluated. Some of the criteria were subjective observations by the live rappellers who participated in the test series. Other criteria were simply objective device qualities. These categories are covered in the rappeller evaluation forms in Appendix C as well as the chart below.

Objective Criteria	SMC Spider	Petzl RIG
Presence of a 'deadman' feature	X	X
Presence of a 'panic stop' feature	X*	
Presence of third party certifications and/or classifications	X	X
Presence of an incorrect loading fail-safe		
Ability to 'stack' multiple devices	X	
Ability to rig/de-rig a rope while attached to a carabiner	X	X

* several of the live rappellers reported that it was difficult to engage the 'panic stop' feature on the SMC Spider.

Ropes

A total of four make/model ropes were examined in the drop test series. Drop tests were repeated on the same rope samples. A variety of time lapses occurred between drop tests; as a result, rope relaxation times were not held constant.

The Bluewater, PMI and Petzl models were all brand-new or new with limited use. The legacy rope was very used and three years old.

The rope elongation properties for the four models are all different. Of the three non-legacy system ropes examined, the lowest elongation was the PMI EZ Bend and the highest elongation was the Petzl Vector. However, despite the differences in elongation properties, the three non-legacy ropes would all be categorized as life safety ropes suitable for rappelling and/or rope rescue applications.

Summary Data

	Ropes			
Force (lbF)	**BlueWater Dynastat 11mm**	**PMI EZ Bend 11mm**	**Petzl Vector 11mm**	**Legacy System**
Minimum	1250	1379	1214	1274
Maximum	1561	1673	1607	1422
Average	1411	1513	1384	1348

As indicated by the data summary, the range of recorded forces for the different rope models were similar. All three of the non-legacy system ropes produced acceptable peak forces given the drop test event that they were subjected to in the test series (i.e. well below OSHA values for maximum allowable force in a harness).

Additionally, no visible rope damage occurred on any of the drops conducted.

Anecdotally, one of the live rappellers commented that a higher elongation rope that was still within the “low stretch” or “static” categorization of rope (i.e. not a climbing or high-stretch dynamic rope) may be preferable in the event of a sudden stop. Specifically, live rappel test #38 used the lowest stretch rope (PMI EZ Bend) and produced a force on the order of 4+ times body weight (1012 lbF). Although still well below the OSHA allowed value of 8kN (1760 lbF), this deceleration force caused some discomfort to the rappeller across his harness straps.

Recommendations:

The drop test series was of a limited scope with respect to the:
- Number of drops conducted
- Number of DCDs examined
- Number of rope makes/models examined

However, despite the relatively small sample size, a number of key observations can be made:
1. The forces generated by the different DCDs were of a similar nature
2. The forces generated by the different rope choices were of a similar nature
3. The forces generated by the Scenario 1 drop tests were below industry-referenced standards for acceptable fall arrest forces (e.g. OSHA) for an adult in a full body harness
4. The forces generated by the Scenario 2 drop tests were below industry-referenced standards for acceptable fall arrest forces (e.g. OSHA) for an adult in a full body harness

The question posed in the Objectives portion of this report was: **“**Are the peak forces being transmitted to the anchor system in the aircraft too high given the combination(s) of the newer, modern devices and ropes?”

The breaking strength of the primary anchor point bracket affixed to the interior of the aircraft is unknown; determining that breaking strength would provide valuable information towards increasing the understanding of the inherent system safety factors.

However, a review of the data obtained in this test series reveals that the forces generated were well within human tolerable limits and were nowhere near the breaking strengths of the ropes or DCDs evaluated. Bear in mind that these were very severe test designs intended to expose a system and/or device weakness. It is unlikely that a live rappeller in an airborne helicopter could produce higher forces than were recorded in the test series.

Moving forward, it seems that the most pertinent information will come from anecdotal use by NPS all-hazard personnel on the rappel tower performing live rappels. Qualities such as the presence of specific safety features, ease of inspection, ergonomics of design and similar criteria will ultimately drive the choice of appropriate DCDs for the helicopter rappel program. The numerous DCD and rope qualities should be rigorously examined through repetitive live rappels in order to properly evaluate device and rope performance in normal helicopter rappelling circumstances.