Equipment & Planning


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Page 83: Matt with just some of the gear it takes to do a long dive. The dock was our departure point to Cenote Turtle Party and Ma' Áayin.

Left and right: The panga boats became crowded places as we geared up for dives at Ma' Áayin.

Coming back safely from the hostile environment of a cave requires specialized training and equipment.

All scuba divers spend time underwater where they can't breathe, but the big difference between *recreational diving* and cave diving is that in a cave, you're in an *overhead environment* and can't go up to the surface if you have a problem, which is the standard emergency response in recreational diving. In this way, cave diving has commonalities with shipwreck diving or deep diving, where there is a *virtual overhead* created by a decompression obligation that similarly prevents an immediate return to the surface. Collectively, these techniques are called *technical diving* for the more complex set of skills, equipment, and techniques that divers must use.

Beyond the overhead, diving in caves has other hazards too. Visibility can easily be impaired, sometimes to zero, by silt. Divers can get lost, lose lights, run out of breathable gas, and worst, panic. These hazards create different and unexpected challenges that divers trained by an organization like PADI in recreational diving techniques will be unprepared to face. As a result, caves have been the site of hundreds of diver deaths, with losses peaking in the mid-1970s. Typically these deaths are attributed to divers that didn't have proper cave training or had some training but didn't use the techniques that we use today. Cave fatalities didn't begin to subside until pioneering cave diver Sheck Exley published in 1979 his treatise called *Basic Cave Diving—A Blueprint for Survival.* Exley's book prompted the cave diving community to adopt the cardinal principles that still form the basis of safe cave diving today.

With the right procedures and equipment, the safety record for well-trained cave divers working within their experience limits is now quite good, and cave explorers tend to view the sport as an activity with risks that can be well-managed. It is not a dare-devil sport. In fact, the modern ideal for cave diving is for the diver to experience a sense of Zen-like calm, with a high degree of finesse and technical precision, achieving not just efficiency in breathing gas usage, but something that for many of us rises to the level of a spiritual experience.


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Left: Matt preparing for a dive.

Right: Most of this gear will go in the pockets of a drysuit, including the jump spools, safety spool, and backup lights.

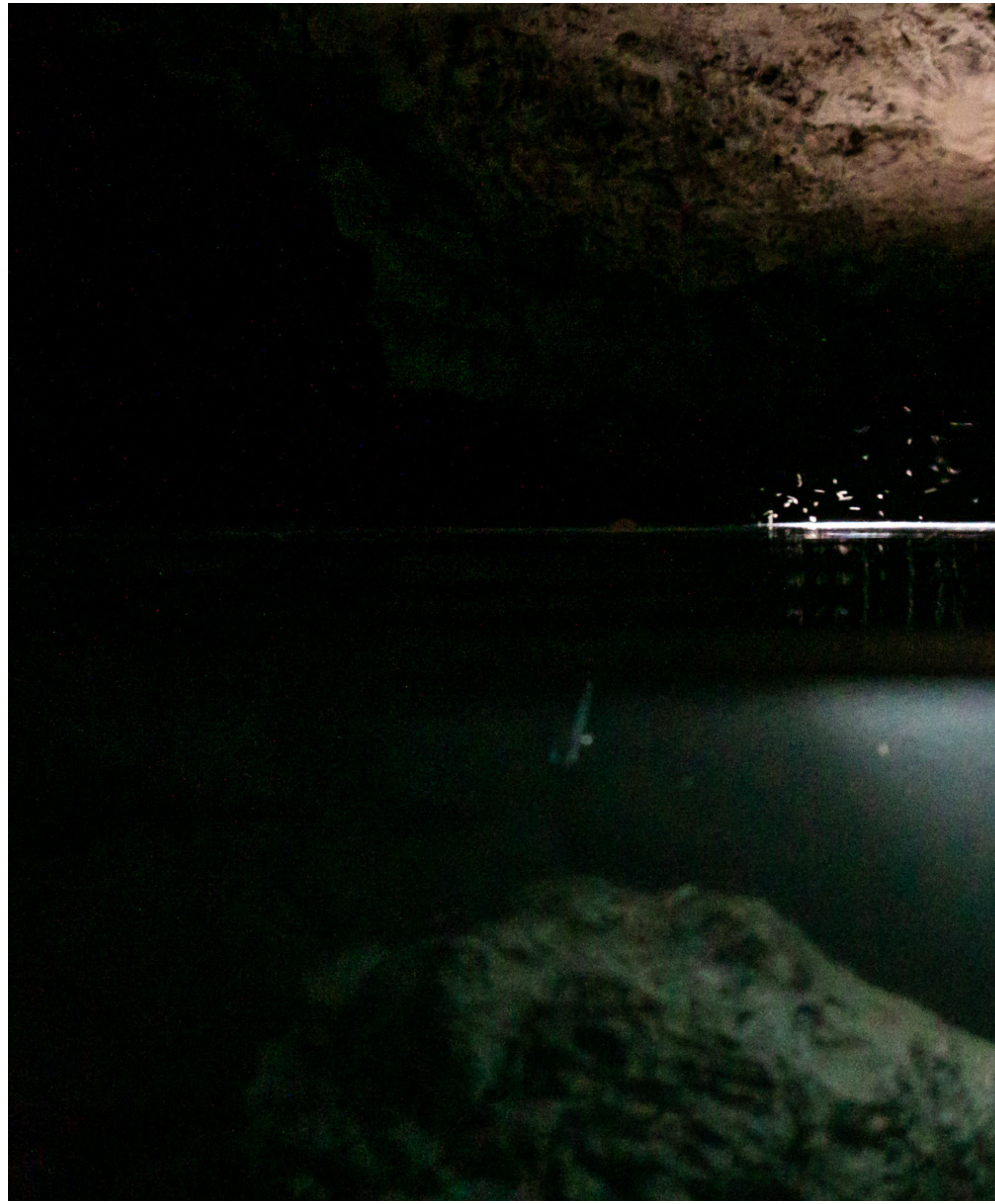
Because problems can't be resolved by "going up," redundancy is a key strategy for diving safely in an overhead environment. We use redundancy of many types—redundancy in equipment (lights, regulators, masks, etc.), redundancy in breathing gas supply, and redundancy in vision and navigation (with a continuous guideline to the surface and proper line marking with redundant navigational aids for each diver).

We also build skills-based capacity for dealing with problems. High-level diving such as cave exploration or cave photography requires extensive training. But it takes the kind of progressive experience that can only be gained by many hundreds of hours in the water to build the muscle memory that puts the mechanics of diving on autopilot so that the diver's extra mental and physical resources can be used to handle problems if they occur.

There is an old saying that *"There are old cave divers, and there are bold cave divers, but there are no old, bold cave divers."* This statement has some truth to it. It is only after divers have gained significant experience that they even begin to "know what they don't know" and realize that some of the risks they took in their learning process could have ended badly. And for those fortunate enough to experience hundreds of dives without any major incident, it takes discipline to keep complacency at bay. Like any black-swan event, potentially catastrophic issues in cave diving are relatively rare but will happen eventually, and divers need to be prepared for them.

Throughout the project, we followed procedures based around the Global Underwater Explorers (GUE) techniques for cave diving. GUE was formed by Jarrod Jablonski and a group of technical divers in 1998, to promote the ideas of team-based diving along with finely tuned technical skills and a standardized set of procedures and equipment. *Doing It Right* (DIR) is the collective term for this approach. While early cave divers frequently dove solo so that they didn't need to worry about anyone else, and each "reinvented the wheel" to solve for their own equipment preferences, many divers now recognize that a great dive partner and standardized equipment and processes bring more mental resources, as well as an extra set of hands, to any problem.

Right: Ivo pops up in an air pocket.



The DIR system was used to push the previous boundaries of long-range cave exploration in the well-known Woodville Karst Plain Project (WKPP) of Florida, and today GUE is a small but highly respected non-profit training and conservation organization for technical and cave diving. Ivo Chiarino, on our exploration team, is one of a small numbers of GUE cave instructors in Mexico

The notable exception to the standard GUE equipment configuration we used on our project was diving with side-mounted gas cylinders, which were required for the small passages of the caves we were exploring.

To walk through our equipment setup, we'll use the Global Underwater Explorers' pre-dive briefing process called *GUE EDGE.* While not a planning process (that happens before we get in the water), the pre-dive briefing allows us to confirm the plan we've already made, as well as perform final equipment checks. We conduct the pre-dive briefing process once geared up for the dive and in the water. GUE EDGE is an acronym:

Goals: The diver in the #1 position on the team states the objectives of the dive, including the navigation plan, and describes tasks such as photography or surveying.

Unified Team: State the role and position of each member on the team.

Equipment Match: The team conducts *equipment matching* to confirm the placement and operability of equipment, including gas sources.

Exposure: State the expected runtime and depth for the dive.

Decompression: State the decompression plan that will be used on the dive. Staged decompression allows us to make a carefully timed ascent to the surface, allowing dissolved inert gas to safely exit our body tissues to avoid *the bends,* an acute illness that can result in arterial gas embolism, musculoskeletal and neurological issues, or even paralysis and death.

Gas: State breathable gas strategy, tank pressures, maximum usable gas and turn pressures, accounting for doubles and stage tanks.

Environment: Identify environmental factors that could impact the dive.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Left: Dropping stage tanks on the line after we've breathed them heading into the cave. We'll continue the dive on our other tanks and then switch back to the stages when we return to this point on our way out of the cave.

The Equipment Match element of GUE EDGE allows us to check that all of our equipment is functional. The most important equipment function is to always have a breathable source of gas. So, we start with a *flow-check* to confirm that our tank valves are open, and then assist each other in looking for leaks at the valve manifold behind our backs, or in our side-mounted tanks and stages, and in hoses that might be difficult to see for ourselves.

After the flow-check, each diver confirms that their regulators can be breathed properly, which might mean testing three or four regulators, one for each tank.

Next, we check to make sure that our *wing* or *buoyancy compensator* and drysuit inflation and deflation valves work. Although the water in the cenotes is a moderate 24 degrees C (76 F), this can become quite cold on long dives without extensive thermal protection. This is especially true for cave divers who make slow and deliberate movements to conserve gas, and who frequently hover motionless as they complete tasks like surveying.

We wear drysuits to stay warm and because they offer a redundant source of buoyancy. Unlike the typical wetsuit that is used commonly in scuba diving, a drysuit doesn't allow any water into the suit, instead employing a waterproof membrane and tight rubber gaskets that seal around the diver's neck and wrists. Entry into the suit is typically through a heavy-duty waterproof zipper along the chest. We wear insulated base layers underneath the suit to help retain heat since the drysuits themselves do not provide much insulation. Wearing a drysuit can be quite uncomfortable while prepping for a dive in the Mexican jungle, but the toasty warmth once we've slipped into the cool cenote water is always welcome.

Because the drysuit is a sealed system, air and water can't move in and out of the suit like in a wetsuit. This provides more warmth but means that the drysuit relies upon the diver's gas supply to equalize the suit's internal pressure with the external (ambient) pressure while descending. Correspondingly, the diver must expel gas from the suit as we ascend. If we couldn't inflate the suit, ambient pressure would squeeze the diver when we descend, and we wouldn't be able to go below about 6 m (20 ft) without physical pain. And when we ascend, the gas in the suit would expand and the suit would turn into a balloon that would cause us to rise to the surface with increasing velocity—a dangerous situation when diving.

While our equipment weighs hundreds of pounds on land, we are completely weightless underwater, thanks to our wing. The wing is an air bladder that attaches to our harness to control buoyancy by inflating or deflating from a valve and hose attached to our tanks. The wing allows us to become neutrally buoyant so that we can hover motionless in the water—neither floating up, nor sinking down. Experienced divers also learn to use their lung volume to make buoyancy adjustments subconsciously, reserving wing inflation/deflation for large changes. Together, our lungs and the wing allow us to hover anywhere in the water column at any depth and with any gear. We can float effortlessly with four tanks, two scooters, a camera rig, and lights—gear that would weigh hundreds of pounds on land but becomes neutrally buoyant in the water.

The wing works with the harness to provide a standardized and highly dependable system. For attaching back-mounted double tanks, we use a harness and metal backplate. For side-mounted doubles, we use a harness with no backplate but instead position our tanks under our arms with bungee cords. Made from simple webbing and a handful of distinct parts (bolt snaps, D-rings, bungee cords, and lead weights), these systems are truly the "glue" that holds cave diving together. These simple and reliable tools are made of materials that can be adjusted or cut underwater if a mishap or entanglement makes it necessary.

For a sport that is so reliant on technology, cave divers tend to bring a kind of conservatism to our equipment choices. While we leverage technology where it provides a real advantage, particularly for batteries, lighting, and scooters, the old saying: *"If it isn't broke, don't fix it,"* applies to the basics. As a rule, we tend to reject nearly all of the gizmos that have crept into recreational diving and use the same trusted fins, harnesses, and masks that have worked for decades.


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Left: Henry points the camera as Ivo hovers nearby in Burrodromo.

Right: A corded primary light, backup lights, and an adjustable wrench that we bring with us on dives in case we need to fix a leaking gas supply hose.

Once in the cave itself, there is absolutely no natural light, so our only source of illumination comes from the gear we bring into the cave. It is important to have redundant lights. We carry a primary light, typically with a corded battery pack and a very powerful and focusable LED bulb, and at least two backup lights.

Lights are also used for communication between divers. Since we can't talk underwater, we are limited to hand signals and light signals. Communicating with our light beams is useful because we don't need to be looking at one another when we signal, and because hand signals aren't visible in many cave diving situations. We have several light and hand signals, some of which are passive and some that require a response. If we can see a partner's light beam on the wall or on the floor in front of us, we can communicate. Communication is kept to a minimum since it creates the potential for confusion, and we should be diving the plan we created before we got into the water rather than "making things up as we go." A steady light beam from each diver means that all is under control, and we don't need to discuss anything else.

We wear a compass on our left wrist, and a dive computer on our right. These tools assist in tracking runtime, maximum and average depth, and in navigation, as well as providing a computer-calculated decompression schedule. We also use some "mental math" for decompression and expected runtime based on our depth and gas consumption. These provide redundancy and more active engagement during the dive.

We try to achieve a very streamlined configuration, avoiding "dangles" and other entanglement hazards. The right-side bellows pocket in the drysuit holds our *safety* equipment, and the left pocket becomes our *working* equipment. We each carry at least one knife or line cutter on our harness, typically attached to a shoulder or waist strap.

The right bellows pocket contains spare lights, hand tools, a backup mask, and a safety spool of line. The safety spool is reserved for the very unusual case of losing visual contact with our primary navigational line and allows us to execute a *lost-line* procedure. Without a backup mask, if our primary mask became lost or compromised, a diver could be required to exit the cave with no visibility at all.

Left: More "pocket contents" and exploration reels of line.

Right: DPVs or scooters that have been "dropped" on the line for a further swim into the cave. The shorter scooters are backups we tow in case of a primary failure.

In our left pocket, we carry our working spools of line for making *jumps* onto other permanent guidelines already installed in the cave, and a *pigtail* that holds navigation markers called *cookies* and *arrows* that we place on the lines to mark the *exit direction* at each intersection we form. There is no safe cave diving without proper line and navigation management. We may carry four or more spools and a dozen cookies and arrows, depending upon the navigation plan for the dive.

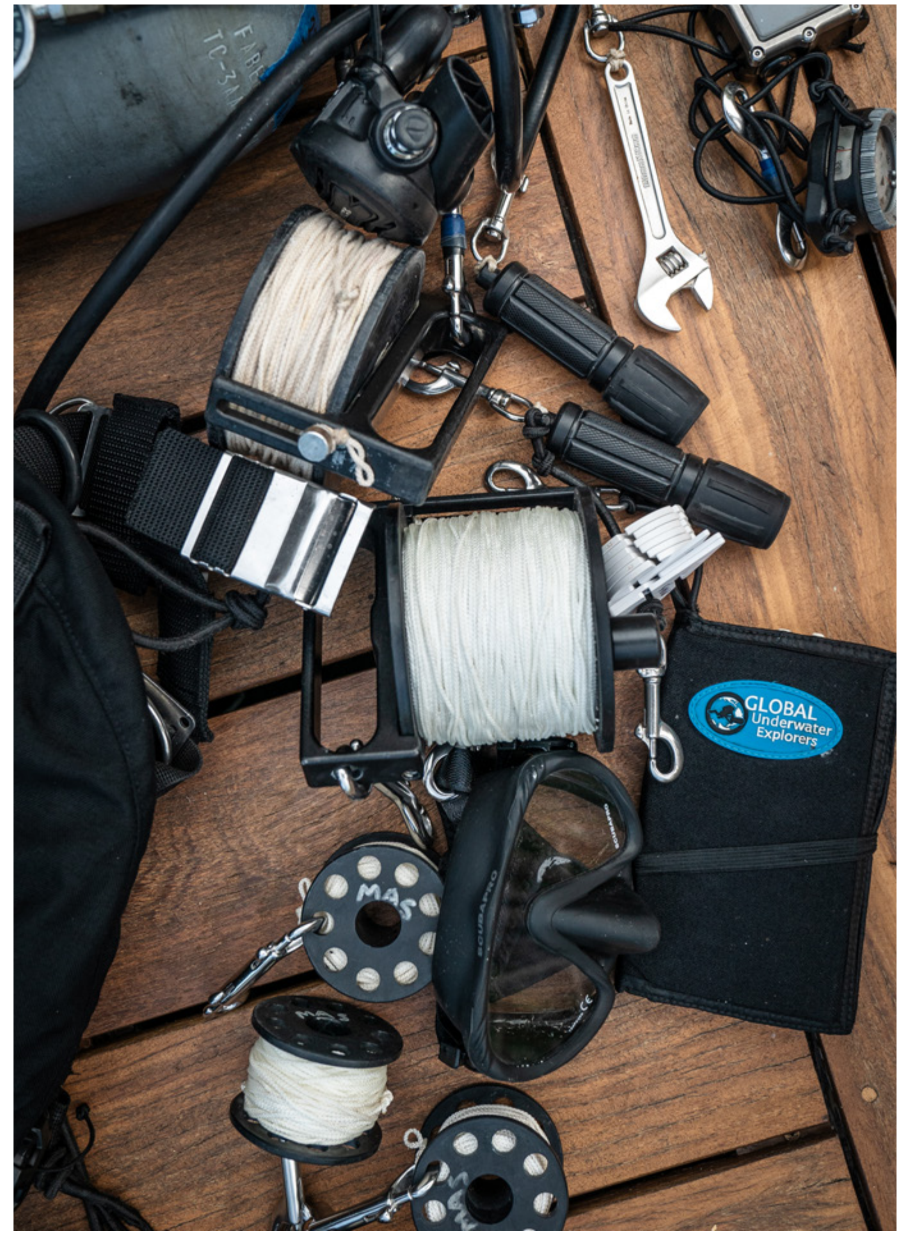
We also always carry *wet-notes,* a small waterproof notebook and pencil that can write underwater. We use wet-notes primarily for writing cave survey data, but they could also be used for communication between divers if absolutely necessary.

We might also bring additional equipment in our pockets or on our harness depending upon the dive plan. This could include the *Mnemo,* an electronic device we use for survey measurements, as well as tape measures, video and camera equipment and lights, and large line reels for laying line when exploring. Depending upon size, these tools may be clipped to a D-ring on the harness or placed in a bellows pocket.

A huge advancement in long-range diving and exploration, Diver Propulsion Vehicles (DPVs), or *scooters,* have revolutionized cave diving by enabling travel well beyond the limits of swimming. We made extensive use of scooters to explore Ma' Áayin as well as the canals. While Ma' Áayin's far reaches are swimmable, the scooters allowed us to quickly reach our last exploration's end point. Scooters were essential for our photography and video dives, as they helped us quickly move a huge quantity of gear into the back of the cave.

Using scooters safely requires considerable judgment and planning. Able to quickly pull divers a long way from "home" means that problems can occur much farther from the cave entrance.

Consider what is now deemed a rite of passage dive for experienced cave divers in Mexico: a scooter ride from the Nohoch Nah Chich entrance all the way to the Blue Abyss, a striking 77 m (235 ft) deep pit in Sistema Sac Actun. Even without descending very deep into the pit, this dive presents complex challenges. The most significant is that if you experienced a scooter failure on the dive, you face a four-plus hour swim back from the Blue Abyss back to the cave entrance—and nowhere close to enough breathable gas left to make it. It is easy to overlook this challenge because the scooter trip into the cave would have taken only an hour and a half.

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Left: We used scooters to get to the back of Ma'Áayin. DPVs attach to our harness with a"leash" that isolates us from the extreme force of drag through the water, allowing our arms to steer the unit with little effort.

Right: Matt and Ivo check the balance and weighting of our scooter-mounted camera setup.

To avoid this situation, our team always carries backup scooters clipped to a D-ring on the harness between our legs. While towing a teammate out of a cave can be done relatively easily in a practice scenario, employing this strategy in a tight cave during a crisis would compound what is likely to already be a stressful situation.

Last but certainly not least important to our project was our camera and videography equipment. This is covered in its own chapter of the book.

After the Equipment Match part of GUE EDGE, we are ready to move on to the Exposure, Decompression, Gas Strategy, and Environment parts of the briefing.

A central element of the dive plan is how we will reserve enough gas to safely complete our cave dive.

We always dive with at least two tanks and usually add additional tanks called stages or stage cylinders to extend our breathable gas range. For longer dives it is common to have three or four tanks, allowing increased range and safety as we explore. Our longest dive on the Mayakoba project was 5.5 hours, and dives of 3.5 to 4 hours were routine.

Because all the caves at Mayaboba were relatively shallow, we used a gas called *Nitrox 32,* which is an oxygen-enriched breathing gas that contains 32% oxygen, 68% nitrogen, and less than 1% other gases.

The gas mixes we use vary by depth, and the shallow caves at Mayakoba simplified our gas management, allowing us to skip helium-based mixtures and pure oxygen which is used for longer decompression diving.

While we did a few dives at Senderos in back-mounted double cylinders, we did most of the project in side-mount, which affords a narrower vertical profile and more flexibility. Side-mount tanks use independent regulators, as does each stage tank. So, if we were diving with our side-mount doubles plus one stage, we would have three independent sources of gas underwater.

Running out of breathing gas in a cave is fatal. To guard against this, we use a gas planning strategy called the *rule of thirds.* The strategy's underlying assumption is that we will come out of the cave the same way we went in. Knowing this, we can plan that we'll use the same amount of gas to exit the cave as we used when entering, theoretically allowing us to divide our *penetration* gas into *halfs.* We can then add redundancy to this plan. Instead of using half of our gas to penetrate the cave, we could use no more than one third of our total gas on the way in and can therefore use just a second third on the way out. The remaining third could then be reserved for redundancy. Ordinarily we will finish a dive with this last third left over; but in a worst-case scenario, a diver could lose all of their gas at the point of maximum penetration into the cave when each has used the entirety of their first third of breathable gas. The diver that lost their gas could then effectively "borrow" the other diver's redundant third by sharing gas on the way out, and in theory, both divers will narrowly exit the cave just as they run out of gas.

Of course, in reality, this rule is more complicated. As you'll note, planning to exit the cave right as you're running out of gas is less than prudent. So, we always conduct our dives more conservatively than the literal rule of thirds. There are other complications too. For example, we adjust gas needs for diving with stages, for water flow in the cave, for scooter diving, and other factors.

After completing GUE EDGE, we signal and descend together facing each diver in a formation like that of a group parachute jump. As things get tighter, we'll take our team positions and head into the cave.

And this is when it really gets good. As we pass a couple of hours into the dive, things really settle in. We breathe slowly; the carbon dioxide we retained getting into the water is now so low that every muscle experiences total weightlessness and a profound sense of ease. Our minds maintain a calm situational awareness for what is happening with the environment, the team, and the team's resources. Visiting the past and future just to complete our picture of the present—a state of *now* that is hard for us to experience outside the caves. ✦

Left: Tanks for a few divers could easily fill our pickup bed.
Center: Matt and Ivo prepare for a dive at Senderos.
Right: Stage and side-mount tanks with regulators.