

Emergency response to incidents involving modern vehicles

Course book



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1. Preamble

Motor vehicles have improved significantly over the last years. They have never been so comfortable, efficient and safe as they are today. They have become more complex due to technical improvements, more electrical components, improved safety systems and new materials, having many advantages for owners and drivers. In addition, the likelihood of becoming trapped following a motor vehicle collision has decreased significantly in the last couple of years, just like the amount of traffic accident fatalities.

From the emergency responder's point of view, this is very positive development, while this increasing complexity may make a safe and fast extrication more difficult. Therefore it is imperative for emergency responders to adapt to the new technologies and the arising challenges. Emergency responders should be trained to handle new vehicle technology challenges and be equipped with the necessary tools for safe and efficient rescue operations. It is certain that it will not be possible to completely eliminate motor vehicle collisions in the foreseeable future. Emergency responders will regularly need to deal with modern vehicle technology.

The intent of this course book is to provide emergency response trainers with the necessary background and knowledge about modern vehicle technology. The intention is not to give a complete and in-depth look at new vehicles, but rather focus on the rescuer-specific concerns related to the vehicles, as well as providing the rescuer with solutions for dealing with these concerns during extrication activities.

This course book also includes some ideas for hands-on extrication training, for rescuers to use while training for motor vehicle incidents.

This course book should provide emergency responders with all the knowledge and information, they really need to know!

Note:

In the following chapters important response procedures are marked with symbols:



Notes for Electro-, Hybrid- und Fuel cell vehicles



Notes for CNG, LPG and Hydrogen vehicles.



Note on restraint systems (airbags, seatbelt pretensioners, roll bars)



Notes on using CRS vehicle information

2. Introduction to vehicle safety

2.1. Safety principles

- Motor vehicle safety has significantly improved over the decade. Ongoing improvements in crash test results are proving this. Furthermore motor vehicle collision fatalities are continuously dropping in areas where these modern vehicles are increasingly found on the street.
- Vehicle safety can be divided in two principles, **active and passive safety**.
- Active safety refers to safety systems that try to avoid accidents, such as:
 - Traction control
 - Anti-lock breaks
 - Electronic stability program

Passive safety refers to safety systems developed for the reduction of the effects of an accident, such as:

- Rigid body structure with crumple zones
 - Airbags
 - Seatbelt pretensioners
- Over the last few years both principles have grown together. New systems also try to reduce the consequences of the accident by actively intervening (braking, etc.) prior to any actual collision impact. At the same time the vehicle's safety systems can "prepare the occupant" for a potential collision by tensioning the seatbelts, closing windows etc.

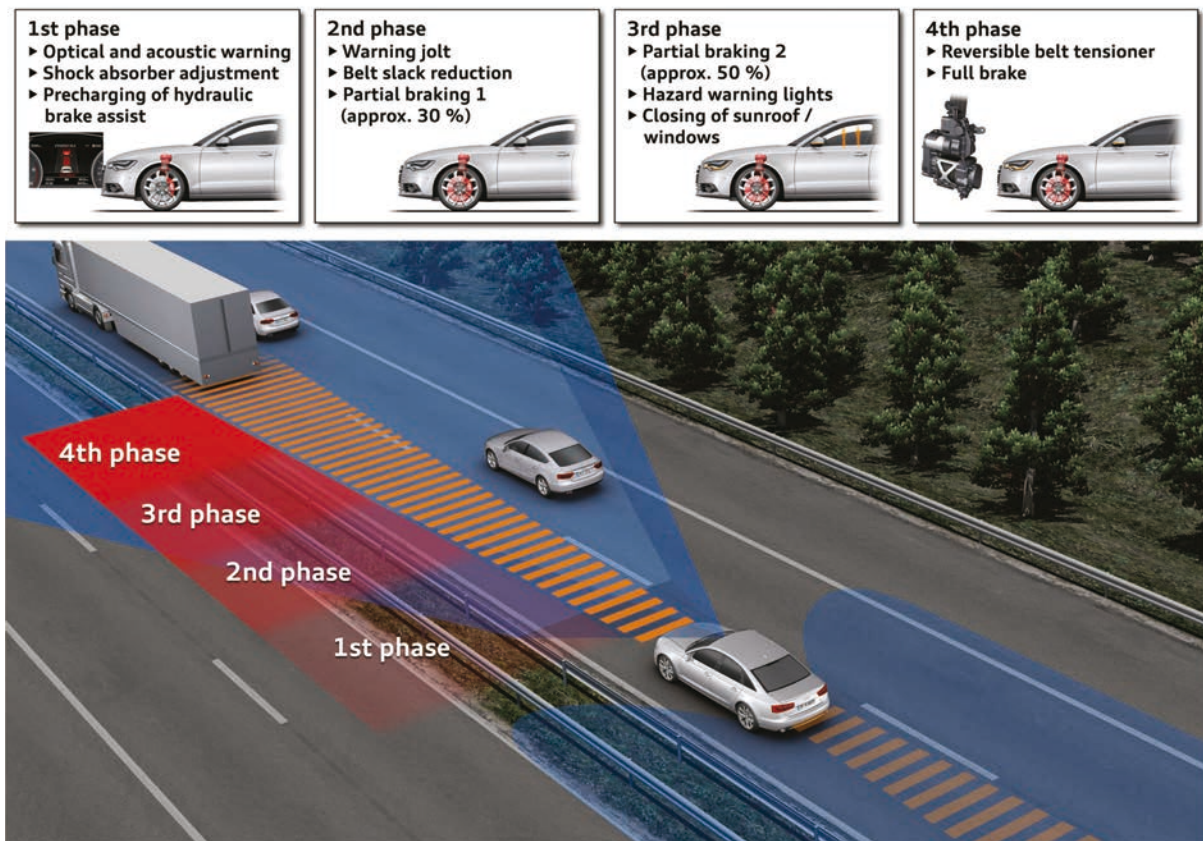


Figure 1: Audi pre-sense front integrated safety feature. The vehicle will begin to apply the brakes and slow the vehicle when approaching a slower object. At the same time the occupant will be prepared for a possible impact (closing windows, pre-pretensioning of the seatbelt). (Courtesy of Audi)

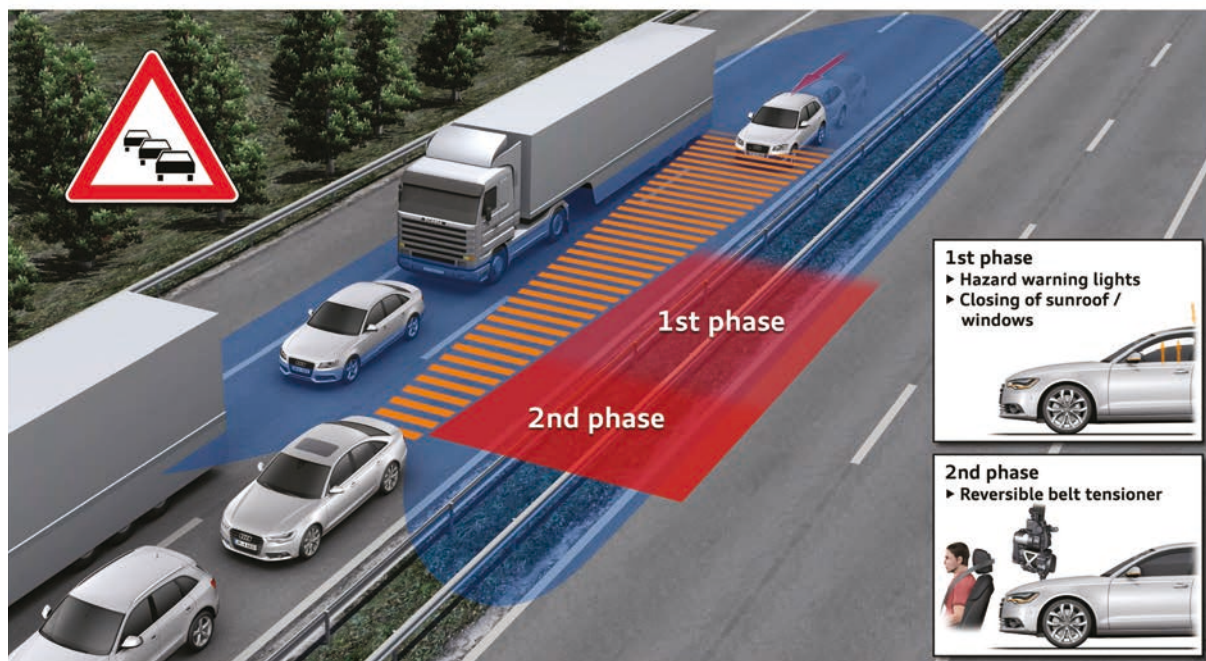


Figure 2: Audi's pre-sense rear integrated safety feature mitigates the consequences of a rear-end collision; it closes the windows and sunroof and tightens the belts if a car is approaching from the rear at a high rate of speed. (Courtesy of Audi)

2.2. Frontal collisions



Figure 3: Body structure of a Mercedes-Benz GL-Class. The arrows indicate the load paths in the case of a frontal collision. The front-end assembly is designed as a crumple zone and absorbs crash energy. The safety cell should maintain its integrity as long as possible. (Courtesy of Daimler)

- In a frontal collision, the front-end assembly can absorb impact energy and reduce the peak loads on the occupants by use of engineered crumple zones. The front-end structure consists of two straight front longitudinal members that deform when subjected to high frontal impact loads. The lateral connections in the front-end activate the side opposite of the impact point in offset frontal impacts.
- In the event of major deformations, the wheels are stopped from entering the safety cage by a strong bulkhead and A-post. This bulkhead is reinforced by an exterior cross member resting against the A-pillars above the pedal floor.
- The reaction of other components such as the **steering column** in a frontal collision is also important. The steering column should not start to move when the front-end structure is deformed in a collision. Therefore it is equipped with cross joints to allow movement of steering column elements without effect on the position of the steering wheel itself.
- Some manufacturers use a **collapsible steering column** design. As the steering column is a potential contact area for the occupant, this design allows the steering wheel and column to be pushed back, a certain distance to absorb energy. Some collapsible steering column designs are using a small pyrotechnic charge to allow the steering column to become collapsible.



Figure 4: A cross member connecting both A-posts protects keeps the engine out of the passenger safety cell. (Courtesy of Volvo)

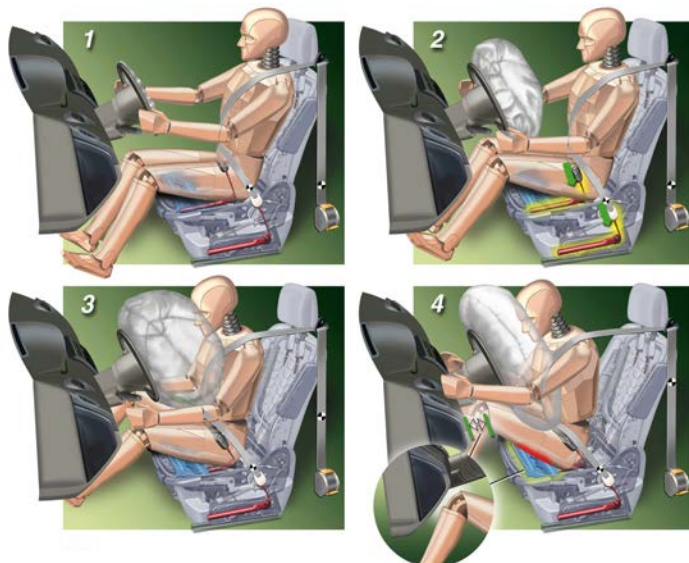


Figure 5: The wheels are pushed against and supported by the strong A-post to maintain the integrity of the footwell area. (Courtesy of Volvo)



Figure 6: Deformation of the front-end structure should not result in steering column movement. For this reason, the steering column is constructed out of several sections connected with cross joints. When the front-end is deformed the steering column section can move without moving the steering wheel. (Courtesy of Volvo)

- The **seatbelt** is the number one lifesaving component of the vehicle. Wearing a seatbelt reduces the likelihood and severity of injuries in a collision by stopping the vehicle occupant from hitting hard against interior elements or other passengers and by preventing occupants from being ejected from the vehicle.
- **Seatbelt pretensioners** are preemptively deployed to tighten the belt to prevent the occupant from jerking forward in a crash. Taking any slack out of the seat belt will ensure that the occupants deceleration can start early in the crash.
- Seatbelt pretensioners may either be mounted on the retractor mechanism, on the seatbelt buckle or on the anchor of the lap portion of the seatbelt. Combinations of different mounting locations are also possible.



- The **driver and the passenger airbag** will be deployed as a supplement to the seatbelt to avoid contact of the occupant with hard surfaces like the steering wheel,

Figure 7: The seatbelt is the most important restraint system. In addition seatbelt pretensioners are used to tighten the seatbelt. Airbags are supplementing the seatbelts by cushioning areas such as the steering wheel to avoid direct impact.

(Courtesy of Renault)

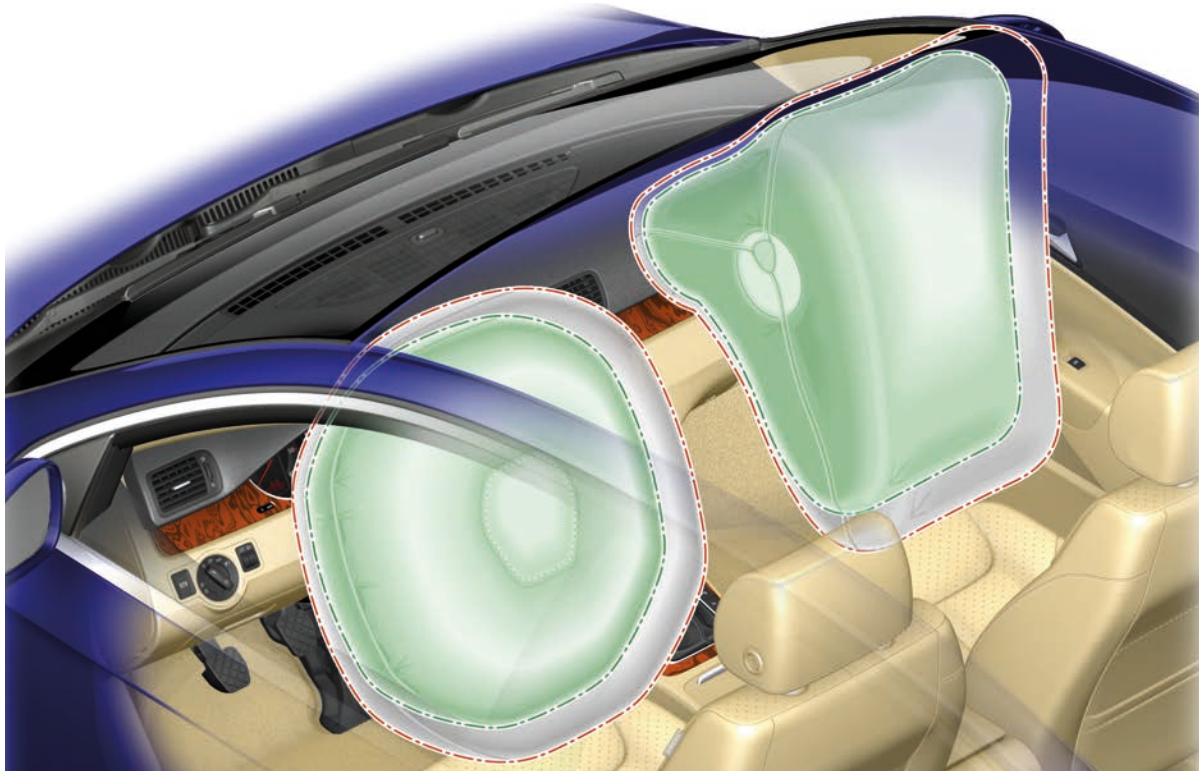


Figure 8: The frontal airbags of this Volkswagen Passat are equipped with dual stage inflators. Depending on the crash characteristic driver and passenger airbags can either be deployed with lower or higher pressure to allow best possible occupant protection. (Courtesy of Volkswagen)



Figure 9: Drivers side knee airbag deploying from the lower dashboard area shown on a Volkswagen Sharan. (Courtesy of Volkswagen)

- Driver and passenger airbag may be able to adapt to crash characteristics in some vehicles. **Adaptive systems** use various vehicle sensor inputs to adjust parameters of the restraint

system. Thus, the vehicle restraint performance can be “tailored” to the crash and the individual driver/passenger occupant situation at the time of the accident. The vehicle sensors may include crash-severity sensing, occupant weight/size categorization and seat position.

- As the airbag inflates, the occupant position and distance sensors help determine the force of deployment. Therefore the driver and airbag module may be equipped with multiple deployment stages (e.g. **dual stage airbag**) or (active) vents to adapt the force and pressure of the deploying airbag.
- While a driver and a passenger front airbag are pretty much standard in modern passenger cars, vans and some trucks, they may be found in vans, and light and heavy trucks. There are also other airbag systems/locations that cannot be considered standard and that are mainly for frontal collisions. These include:
 - **Knee airbags** may be located on the driver and passenger side lower instrument panel. They deploy outward from the instrument panel to shield the knees of the driver and front seat passenger from direct impact with the instrument panel. They will deploy during a frontal impact at the same time as the driver and passenger airbag.
 - **Anti-submarining airbags** (also referred to as seat-cushion airbags) may be mounted within the front or rear seat cushion. Following a frontal impact they lift the front of the seat cushion together with the occupant’s legs to reduce the risk of ‘submarining’, which occurs when a passenger slides forward under a loosely worn lap belt.



Figure 10: This Toyota/Scion iQ features an anti-submarining airbag in the seat. The airbag lifts the front of the seat cushion to avoid the submarining effect. (Courtesy of Toyota)

- **Seatbelt airbags.** The fully inflated belt helps to distribute crash force energy better across the occupant’s body and reduces injury risks. The inflatable seatbelt utilizes

an inflator mounted to the buckle of the seatbelt that is connected to the seatbelt as soon as the seatbelt is fastened.



Figure 11: Inflatable seatbelt (belt-airbag) shown on the rear-seat occupants. The inflatable seatbelt distributes crash force energy better across the occupant's body. (Courtesy of Ford)

2.3. Side collisions



Figure 12: Body structure of a Mercedes-Benz GL-Class. The arrows indicate the load paths in case of a side collision. Unlike frontal collisions the distance between the occupant and the side structure is limited. Therefore there is no real crumple zone to absorb energy. The car

manufacture tries to reinforce the side structure in order to reduce intrusion to the passenger compartment. (Courtesy of Daimler)

- In order to maintain the integrity of the vehicles structure in side impact collisions the structure of a modern passenger car is highly reinforced to reduce intrusion, leading to direct contact of the occupant with the side structure.
- Reinforcements in the doors (such as crash bars, pipes or profiles) help to distribute crash force from the door to the vehicle pillars, trying to avoid severe intrusion to the passenger compartment itself.



Figure 13: Seat-mounted side airbags for front and rear seat passengers are shown on this photo along with the curtain airbag deploying from the roof rail of the vehicle. (Courtesy of Daimler)

- **Seat-mounted side airbags** may be located in the seam in the outer edge of the front or rear seat to cushion the thorax of the occupant in a side collision. Some airbag designs will also deploy upward to also protect the occupants head area.
- Some manufacturers are using more than one side airbag per seat. The **pelvis airbag** for example deploys from the area of the seatback hinge and covers the area of the occupant's pelvis while the seat-mounted side airbag covers the thorax area of the occupant. Some vehicles also have an additional **head airbag** deploying from the upper portion of the seatback to cover the occupants head area.
- An alternative location for side impact airbags is the **door-mounted side airbag** located in the door panel or inside the rear quarter panel.



Figure 14: Seat-mounted side airbag extending upwards to cover the occupants head. (Courtesy of Daimler)

- The **curtain airbag** design typically covers the side structure of the vehicle in a side collision protecting front seat as well as rear seat occupants. It deploys downward from the roof rail. In some earlier models, an “inflatable tubular structure” was used. This airbag deploys downward from the A-pillar and roof rail, creating a rigid diagonal tubular structure that stays inflated for some time.



Figure 15: Door-mounted side airbag combined with an ITS (Inflatable Tubular Structure) head impact airbag. (Courtesy of BMW)



Figure 16: Front center airbag shown on a GMC Acadia. (Courtesy of GM)

- Some vehicles also utilize a **center airbag** design where an airbag deploys from the inner edge of a front seat. During passenger-side crashes when the driver is the only front-seat occupant, the airbag functions as an energy-absorbing restraint. It also provides an energy-absorbing cushion between the driver and front passenger in driver- and passenger-side vehicle collisions.
- **Curtain airbags may** also potentially deploy **in some frontal collisions** to avoid contact of the occupant with the roofline or the A-post.

2.4. Rear-end collisions

- In case of a rear-end collision, the rear of the vehicle is designed to act as a crumple zone and should absorb crash energy.

- In addition some vehicles may deploy the **seatbelt pretensioners** in order to keep the occupant in the seat. In case of a rear-end only collision it is unlikely that any side or frontal airbags will deploy.
- The risk of whiplash injuries in the event of a rear impact collision may be reduced by special **whiplash protection systems**. Some systems are designed to move the headrest forward and up within a matter of milliseconds to support the heads of the front passengers in an early stage and help to prevent hyperextension of the cervical spine. They are either engaged by the occupant's weight, a preloaded spring or a small pyrotechnic charge. In some cases the whole seatback moves together with the occupant in order to protect the front occupant's neck.
- Some vehicles also utilize a **rear curtain airbag**. The airbag deploys from the roof lining above the rear window in the form of a curtain-like barrier. Together with the headrests, the airbag minimizes impact to the head from colliding vehicles or parts of the vehicle being hit.



Figure 17: Daimler's Neck-Pro whiplash protection system reduces the clearance between the occupant's head and the headrest in order to avoid hyperextension of the head. (Courtesy of Daimler)



Figure 18: In Volvo's WHIPS (Whiplash Protection System) equipped seat, the entire seatback is designed to move together with the occupant in a rear-end collision. Therefore they are equipped with a piece of metal inside the seat that absorbs energy. (Courtesy of Volvo).



Figure 19: Rear curtain airbag shown on a Toyota/Scion iQ. (Courtesy of Toyota)

2.5. Rollover collisions

- In a rollover collision the safety cell should stay intact to insure survival space for the occupants. Special tests are conducted to test the crashworthiness in rollover collisions and to assess the roof strength of a vehicle.
- Some vehicles are equipped with a rollover sensing system that may **deploy seatbelt pretensioners and curtain airbags** in a rollover crash to keep the occupants in their seat and to avoid direct impact on the B-post and side structure. The curtain airbag may also prevent ejection of an unbelted occupant.
- Some special considerations have to be taken into account in case of **convertible or retractable hard-top vehicles**:
 - The A-pillar of a convertible needs to be reinforced in order to prevent it from collapsing in a rollover collision minimizing the survival space for the occupants. Therefore heavy reinforcements are used in most modern convertible A-posts.
 - Automatic **Rollover protection systems** (“ROPS”) are used on some convertible or retractable hardtop vehicles if not equipped with a fixed roll-bar. They are designed to flap- or pop-up from behind the rear seat in case the vehicle rolls over, thus maintaining enough survival space for the occupants. Rollover protection system work in conjunction with the reinforced A-post.
 - Convertibles and retractable hard-top vehicles cannot be equipped with standard curtain airbags mounted to the roof rail of the vehicle. Therefore **door-mounted curtain airbags** are used in those vehicles. Those airbags deploy up from the upper edge of the door instead of deploying down from the headliner. However, this airbag design can also be found on vehicles other than convertibles and retractable hard-top vehicles.



Figure 20: The safety system of convertibles has some special features. This images shows a door-mounted curtain airbag design as the curtain airbag cannot be stored in the retractable hard-top. The vehicle is also equipped with a rollover protection system behind the rear seats and a reinforced A-post. (Courtesy of Volvo)

2.6. Pedestrian safety

- Most pedestrian deaths occur due to head injuries resulting from the severe impact of the head against the hood and windshield. While the hood itself is usually fabricated from sheet metal, which is energy absorbing, most injuries occur when there is insufficient clearance between the hood and the rigid underlying engine components.
- For this reason, the front of modern vehicle is specially designed to reduce the peak contact forces, especially by making the bumper softer and by creating more clearance between the engine hood and the engine itself. Some manufacturers are using a so-called 'pop-up hood' in order to create this clearance. The pop up hood raises parts of the hood by means of pre-tensioned springs, pyrotechnic charges or small airbags to soften the impact of the pedestrian.



Figure 21: Pedestrian Protection System shown on an Audi A3. Sensors in the front bumper are able to detect a collision with a pedestrian. On detection two pyrotechnically released pistons will lift the rear edge of the hood. This increases the clearance between the hood and engine parts. (Courtesy of Audi)

- In some portions of the hood it is more or less impossible to soften the contact area, such as the edges or the cowl, where the hood meets the windshield. Some car manufacturers have attempted to overcome this problem by activating a **pedestrian airbag** that lifts the hood and cushions those areas.



Figure 22: Pedestrian airbag shown on a Volvo V40. If a collision with a pedestrian is detected the hood hinges will be released by firing two pyrotechnic charges. The pedestrian airbag will inflate, raising the hood approx. 10 cm in the process to help absorb some of the impact. The airbag covers the lower edge of the windshield and the A-pillars in order to reduce the severity of head injuries from impact with these structures. (Courtesy of Volvo)

2.7. Post-crash considerations

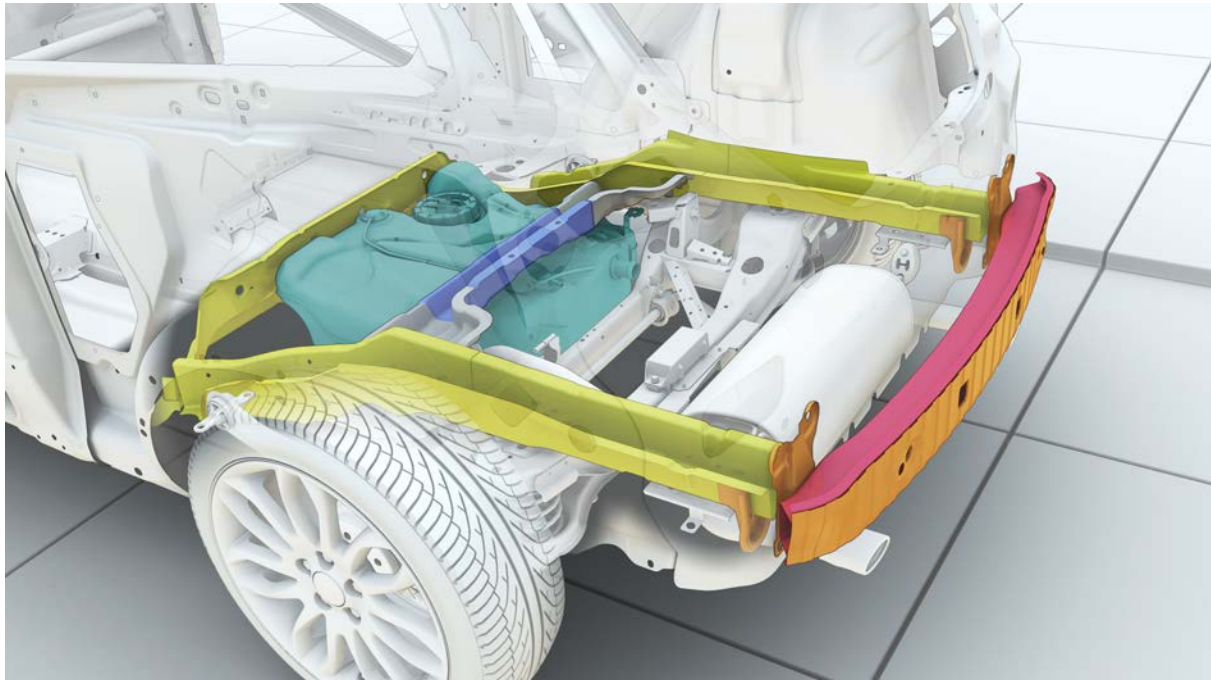


Figure 23: Protected mounting of a fuel tank in the area of the rear axle (courtesy of Volvo).

- In order to keep the occupants safe following the collision vehicles manufacturers try to reduce risks, such as a post-crash fire situation.
- Relevant components of the propulsion system (such as the fuel tank or high voltage battery) are mounted in protected areas of the vehicle not likely to be damaged in a crash. Those areas can be found around the rear axle and in the center of the vehicle.
- Based on the detection of an accident, the SRS control unit can also trigger additional events, such as:
 - Shutting down the propulsion system by switching of the fuel supply to the engine, thus reducing the risk of fire when fuel is pumped through damaged lines.
 - Unlocking doors that have been locked during driving. This will enable emergency responders to gain easy access to the occupants as long as the doors are not jammed.
 - Switching on the exterior hazard lights. This will warn others and allow for an easier recognition of the crashed vehicle.
 - Initiate emergency braking to avoid secondary collisions, preventing the vehicle from continuing to roll after impact.
 - Switching on the interior lights. This will ease orientation for the occupants.
 - Calling for help. Some manufacturers offer an automatic collision notification service that will notify a service center in case of a collision with airbag deployment. In the near future, every type approved vehicle in Europe will have an automatic collision notification system (eCall) working with the pan-European emergency number 112.

3. Body and materials

- Modern vehicles are equipped with a significant amount of high-strength and ultra-high-strength steel. Those materials are typically found in potential “cut-zones”, where emergency responders need to cut and spread following severe collisions. It is a known fact that some of those reinforcements cannot be cut with older hydraulic cutters or with reciprocating saws. There is also a high probability that these reinforcements may even damage the rescue tool.
- As an alternative to steel and to save weight, materials such as aluminum, plastic or magnesium may also be used in parts of the vehicle structure.

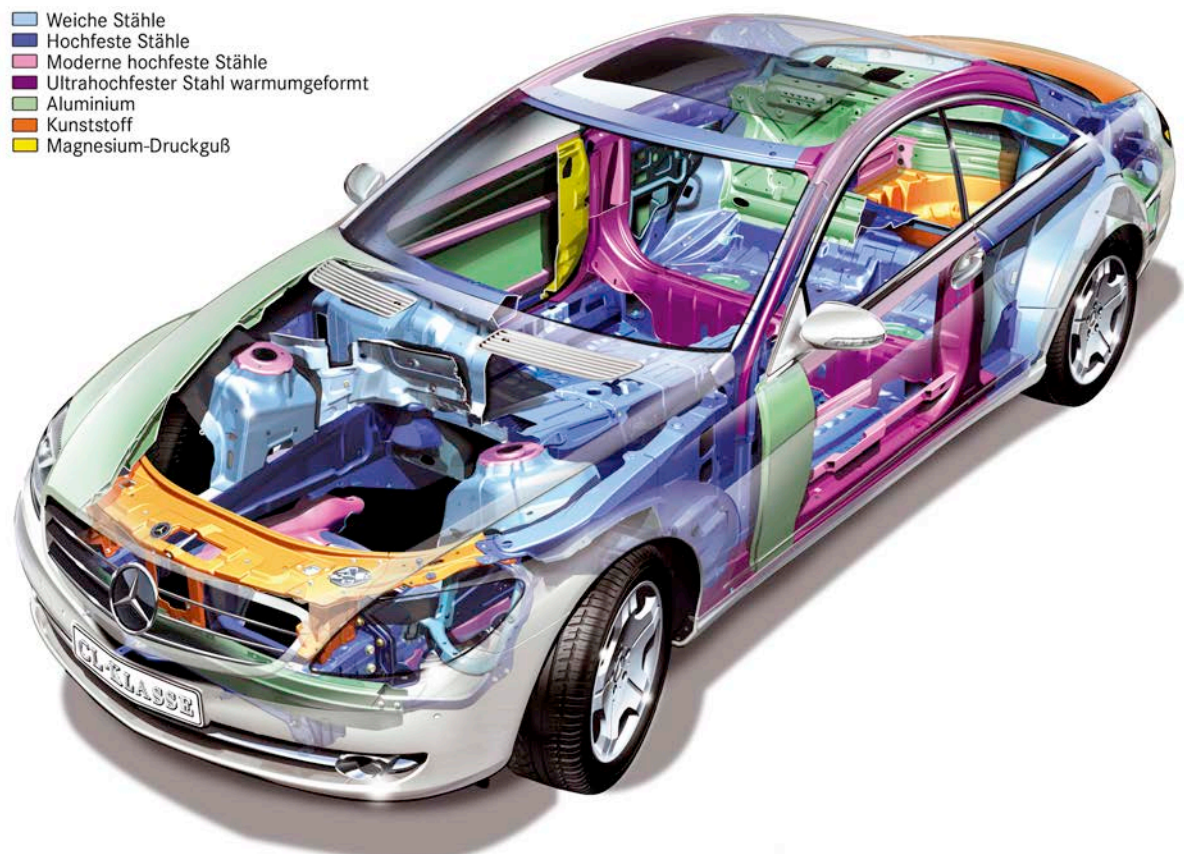
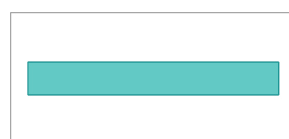


Figure 24: This Mercedes-Benz CL coupe is a good example to demonstrate the amount of ultra-high strength steel used in a modern vehicle body. The vehicle’s body also includes alternative materials such as plastic or magnesium used in the structure of the vehicle. In addition this vehicle is also equipped with a reinforced steel pipe in the A-post to ensure survival space during a rollover accident. This is because a coupe vehicle originally lacks the B-post. (Courtesy of Daimler)



Note:

The location of reinforcements is indicated in the CRS diagram. Additional information of the type and category of the reinforcement can be found in the interactive information that is displayed when clicking on the reinforcement.



Reinforcement

- The question if a reinforcement made of high-strength steel or ultra-high-strength steel can be cut with a hydraulic cutter cannot be easily answered as this depends on the tool itself, the type of blades and the skills of the tool user.
- Crash Recovery System information should therefore be used as an indicator, that an area is reinforced. The available tools should also be taken into consideration. The Crash Recovery System provides detailed information about the locations of the reinforcements, so that workable alternatives can be found, saving valuable time and effort.

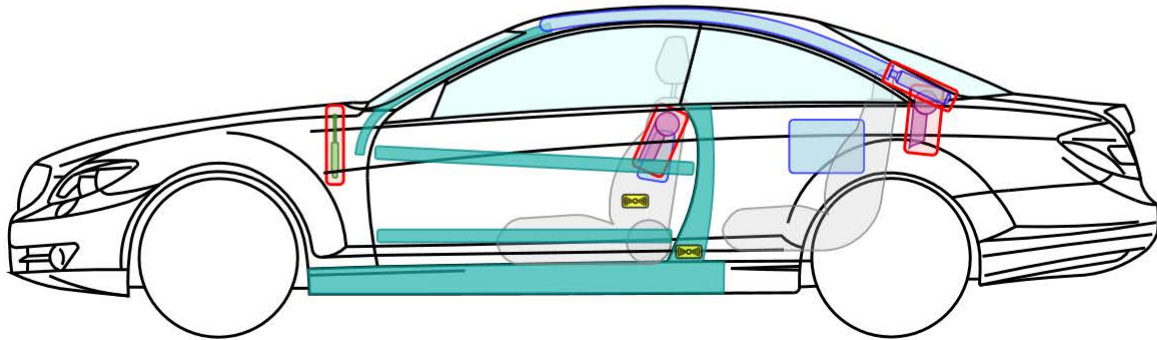


Figure 25: The CRS diagram of the Mercedes-Benz CL clearly indicates the reinforced areas, such as the A-post, rocker panel and B-post.

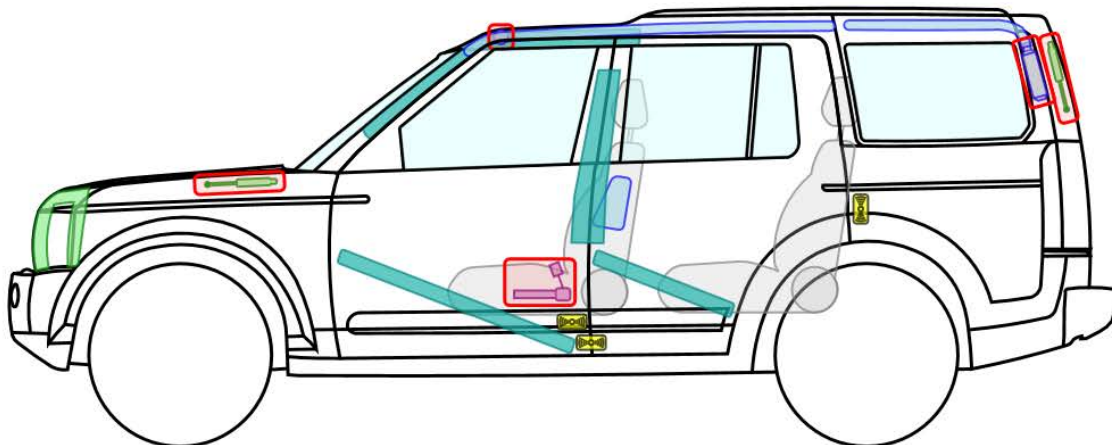


Figure 26: The CRS diagram of this Land Rover Discovery indicates reinforcements in the A- and B-post as well as in the roof rail. Avoiding the reinforcement in the B-post is quite simple by cutting above or below the reinforced area.

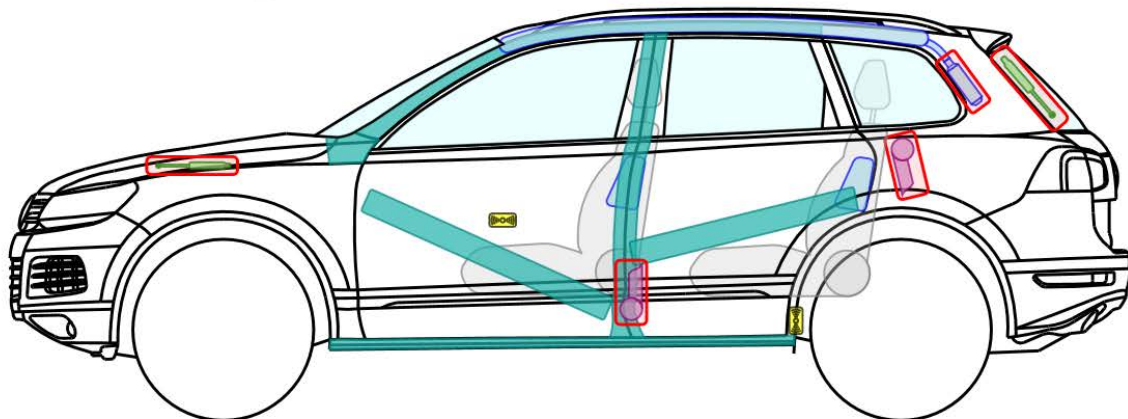


Figure 27: The CRS diagram of this Volkswagen Touareg shows reinforcements in the side structure. When the A- or B-post needs to be cut, there is no obvious best cutting point. The type of rescue tool and the skills of the operator are the deciding factor if it can be cut.

3.1. Extrication planning for vehicles with heavy reinforcements

Plan A, B and C

- Knowing where the reinforcements are allows the tool operator and incident commander to make decisions based on the actual vehicle equipment at an early stage in the incident.
- Rescuers should always have a plan B in case their plan A fails, for instance, because a reinforced post cannot be cut.
- It cannot be said that a reinforced roof post cannot be cut with hydraulic rescue tools. . Therefore cutting the posts can be a valid “plan A” to try to cut the reinforced areas, however this evolution may not work. Be patient on vehicles where structures are reinforced with steel pipes. Experience has shown that those are most difficult to cut, even with some late model cutters.
- For a plan B it is possible to slightly adapt existing techniques, for example: Instead of a total roof removal (plan A) on a vehicle with a pipe reinforced A post, plan B may be to flap the roof forward.

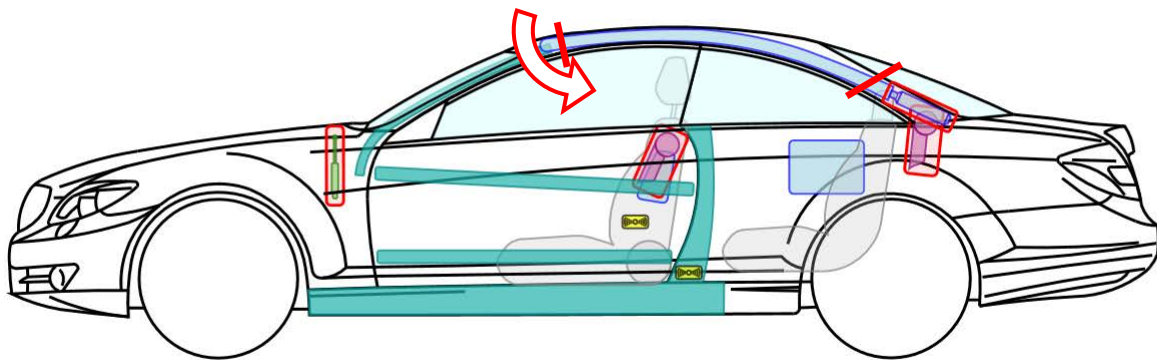


Figure 28: Instead of totally removing the roof (Plan A) it is possible to flap the roof forward by just making a relief cut behind the A-post reinforcement. Flapping the roof forward will also eliminate the need to cut through the laminated windshield.

- Plan B may be to just cut around the reinforced area. For example: Knowing where the reinforcement ends may allow to cut around the reinforcement(s).

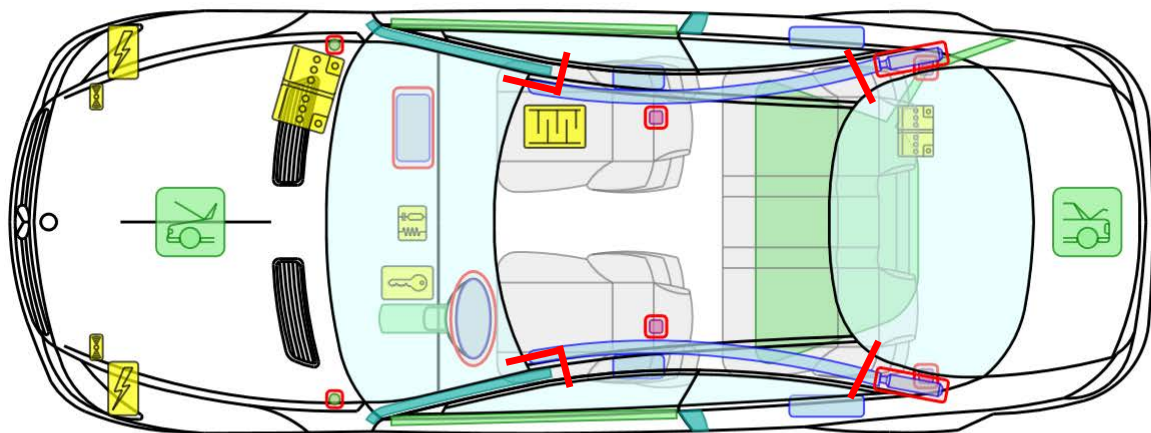


Figure 29: Plan B could be to avoid the reinforcement by cutting around it. The Crash Recovery System indicates the exact location. After removing the windshield it is possible to work around the pipe making cuts, one longitudinal and one transverse.

- Plan B may also include using an alternative tool, such as a reciprocating saw or a circular saw.

Flexibility

- Materials used in the vehicle body, such as aluminum, plastics or magnesium may also make it more difficult to use well known techniques. Therefore it is very important to remain flexible. Emergency responders should be capable of using different techniques for similar problems to be able to react accordingly if one method fails.

Less is more

- Extrication evolutions may take longer because of the complex construction of modern vehicles. Keep focused on the overall target to extricate the occupant as safe and quick as possible. There might be alternative pathways that are easier and faster to achieve goals, even if it may be less convenient for the rescuers.
- One such example is using existing openings in the vehicle. For example, it may be possible to extricate the patient through the rear of the vehicle. Seats can often be removed or folded out of the way to get a free pathway. Even in a worst case scenario where only a small rear window opening is present (such as on a coupe or sedan) it is often possible to widen this opening with hydraulic tools. Compared to a partial or total roof removal this only requires one tool evolution and therefore may be much faster.

Teamwork

- Keep in mind that multiple hydraulic cutters (probably in combination with a reciprocating saw) can be used at the same time to reduce the overall extrication time. Nowadays most hydraulic power units allow the simultaneous use of two tools.
- Extrication often involves the alternating use of multiple rescue tools. The incident commander should make sure that the next tool is ready for operation when the last evolution has been finished.
- The spreader and the cutter should always be available for immediate action. The alternating use of cutter and spreader may overcome challenges associated with new materials, such as separating doors while spreading. Quickly cutting away the lock mechanism when enough space has been gained may be the faster option but requires the immediate availability of the cutter.



Figure 30: The front fender of this Volkswagen Touareg is made of plastic. Squeezing the fender has not been a successful method to get access to the door hinges. The tool operator needs to be flexible enough to go to Plan B and use another tool evolution to reach that goal.



Figure 31: The photo shows an example of a method to quickly create a pathway for extrication through the rear window. Instead of totally or partially removing the roof of the vehicle the rear window opening can be widened with the spreader by either pushing the roof up or the speaker deck down.

3.2. Cutting and spreading techniques to cope with heavy reinforcements

Making maximum use of hydraulic cutters

- As with every other tool, hydraulic rescue tools require a certain level of training in order to get maximum output.
- In order **to reach the maximum force** of a hydraulic rescue tool, the operator needs to **wait for the hydraulic pump to reach the maximum pressure**. Depending on the manufacturer this may take several seconds and requires the tool operator to keep 'the finger on the trigger'. A hydraulic rescue tool has its maximum force only when maximum pressure is reached.
- A hydraulic cutter has its **maximum force at the point where both blades are connected**. Therefore it is very important to open the cutter fully before cutting. If the cutter is pushed away, consider to squeeze the material with the cutter blades and reposition the cutter. If possible, do not cut with the tips only.
- Door frames and other components may overlap with reinforced vehicle pillars and serve as distance keepers when a rescue tool is used on the pillar. The strongest part of the cutter blades may simply not be able to reach the reinforced parts as the door frame keeps the cutter away from the roof post. Therefore it is possible to **remove these distance keepers** before the cutter is used on a reinforced roof pillar.
- A hydraulic cutter gets more force when it closes. Therefore consider to cut profiles in length and not in width.
- To allow the vehicle occupant to adjust the height of the seatbelt some vehicles allow moving the seatbelt up and down on the B-post. The **seatbelt attachment bracket** additionally reinforces the roof post and should be avoided during cutting.
- If the cutter stalls, try to reposition the cutter more than 90° and cut again. This may further weaken the material and allow the cutter to cut it finally.

Ripping materials

- Ripping may be used as an alternative (Plan B) for cutting.
- When a rescue team cannot cut through a B-pillar or roof rail the backup plan can be to **ram the roof off the top of the B-pillar**. Even though ultra-high strength steel may be present, the ram may be able to push the roof rail up until it begins to tear at the spot welds.
- The ripped material will always **tear on the weakest location**. It is not necessary to know where this location is. Unfortunately this location may also be where you don't want it to tear.
- Ripping may also be used on wide roof posts (such as C- and D-posts) and can also be **performed with a hydraulic spreader**.



Figure 32: The B-post of this Mercedes-Benz S-Class has been ripped off by utilizing a hydraulic ram. The ram has been extended from the rocker panel to the roof rail to apply force on the B-post. In this case the roof could be ripped completely off the B-post.



Figure 33: A telescopic ram is used to “ram” the roof of the B-post on this Volkswagen Tiguan. The initial push is performed behind the roof post. Note the wooden wedge that is used to protect the piston of the ram from being damaged by the ripped metal. After repositioning the ram to the front of the pillar the roof could be completely ripped off. Note the rocker panel support and the cribbing under the rocker panel to make sure the ram does not penetrate the rocker panel.



Figure 34: The spreader is utilized to rip the C-post of this Volkswagen Sirocco. Initially the tool operator unsuccessfully tried to completely cut the C-post with a cut from the left and from the right. Instead of trying to connect the two cuts he then utilized the spreader to rip through the remaining part of the roof post instead of trying to cut the remaining part of the roof post.



Figure 35: The rear portion of the roof sheet metal has been lifted with a hydraulic ram. Initially it may be necessary to make a relief cut at the left and right edge of the roof to define a starting point. Note that the roof has been ripped off at the weld spots where it has been attached to the roof rail.



Figure 36: A hydraulic cutter is used to extend the rear window opening by creating a 'roof spoiler'. Cutting through the rear roof edge on the left and on the right side may allow to bend the center part of the roof forward and may already gain enough space to extricate an occupant through the rear window.

Pushing away vs. cutting

- Instead of totally removing certain vehicle components on a modern vehicle it may be more sufficient and time-effective **to just push them out of the way**.



Figure 37: The roof of this Mercedes-Benz C-Class has been pushed out of the way instead of being removed completely, allowing to extricate the victim through the rear of the vehicle. This technique works best on vehicles with three roof posts. When force is applied on the center post on the uncut side, the roof will rotate upwards.

Using weak areas

- The “using weak areas” concept refers to techniques focusing on areas of the vehicle that **are normally not reinforced** with ultra-high strength steel.
- One such example is the roof of the vehicle. It may be much easier to **cut through the sheet metal of the roof** using a reciprocating saw instead of cutting the individual roof posts. Making two longitudinal cuts from the rear of the roof to the front of the vehicle may allow flapping the center portion of the roof forward (**fish-can method**). It may also be possible to only cut one side of the roof and then flap the roof to the other side. Note: Some vehicles feature an ultra-high strength steel cross member. A reciprocating saw may not be able to cut through that cross member.
- Instead of cutting through the roof posts it may also be an option to work your way through the trunk (**tunneling through the trunk**) of the vehicle to extricate the occupant through the rear of the vehicle. Neither the trunk lid nor the speaker deck is reinforced, making it easy to remove those components with hydraulic or electric tools. After removing the rear seatback the pathway is free. Keep in mind that it may be difficult to work through the trunk of the vehicle if a high-voltage battery or similar device is mounted in this area.



Figure 38: The sheet metal roof of this Volkswagen Golf has been cut on both sides with a reciprocating saw. Following the cuts it has been flapped forward together with the headliner. This allows enough space to extricate the driver to the rear of the vehicle.



Figure 39: Tunneling through the trunk of an Audi S5. The rear hatch has been removed with a hydraulic cutter. The speaker deck has then been cut out with a reciprocating saw and a hydraulic cutter. In a last step the rear seatback has been spread out of the vehicle.

4. Restraint systems

4.1. Restraint system electronics

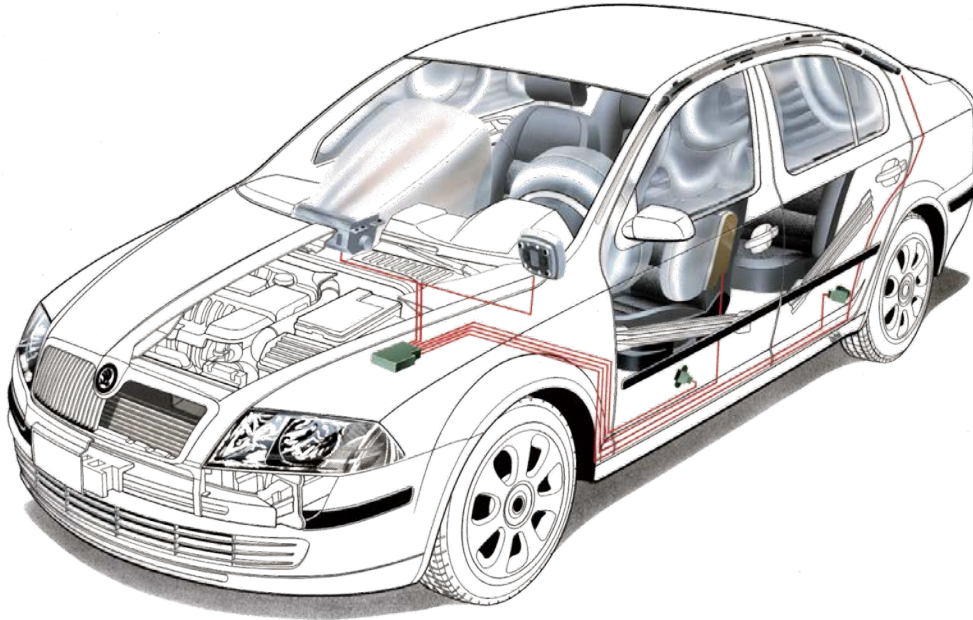


Figure 1: Supplemental restraint system. The graphic shows sensors in the side structure, the SRS control unit on the center tunnel and driver, passenger, front seat-mounted side airbags as well as curtain airbags. (Courtesy of Skoda)

- The **SRS control unit** monitors a number of related internal and **external sensors**, such as impact sensors, acceleration and pressure sensors. When a preset threshold has been reached or exceeded, the SRS control unit will trigger the ignition of the attached restraint systems, such as airbags, seatbelt pretensioners and rollover protection systems.

Note:

The SRS control unit will only deploy certain restraint systems depending on the accident situation (see Chapter 1). It is not likely to find a find vehicle equipped with six or more airbags with all devices deployed!

Note:

Some older vehicles utilize **mechanical sensors**. These sensors operate independent from the ignition status and from the 12/24 Volt electrical system.

- Most SRS control units are equipped with a capacitor retaining energy to deploy the restraint systems in case the vehicle's electrical system is damaged early in the crash. **Drain down times of these capacitors vary** from a few milliseconds to up to 30 minutes depending on the manufacturer.

Note:

The SRS control unit and sensors are active as long as the ignition is switched on. The drain down time of the SRS control unit's capacitors will start as soon as the ignition has been switched off.

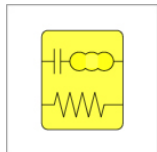
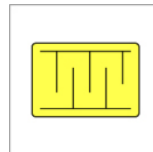
- Some vehicles are equipped with a **seat occupancy sensor** (occupant classification system) on the front passenger's seat. A seat occupancy sensor will prohibit the deployment of restraint systems for the front passenger in case the seat is unoccupied.

**Note:**

The locations of restraint system electronic components are indicated in the CRS diagram. Note that a mechanical sensor (independent from the 12/24 Volt electrical system) is marked with a red frame.



Sensor front / side

Sensor front / side
(mechanical)SRS control unit
Roll bar control unit

Seat occupancy sensor

4.2. Airbags

- An airbag module generally consists of an inflator and the airbag itself. The inflator may either work with pyrotechnics, stored gas or with a combination thereof and generates the gas required to fill the airbag within a couple of milliseconds.



Figure 40: Cutaway model of a driver airbag. The pyrotechnic inflator is visible in the center of the steering wheel. Once ignited, the pyrotechnic charge will produce a large amount of nitrogen gas to fill the airbag in a couple of milliseconds. The inflating bag tears open the cover and expand to its maximum volume. (Courtesy of Daimler)

- Emergency responders may face two potential dangers when dealing with a vehicle with undeployed airbags. **Airbags may be deployed** due to manipulating around sensors or creating shorts while working on the vehicle with rescue tools. In addition cutting or otherwise **damaging stored gas inflators** may lead to flying projectiles or to unintended exposure of the pyrotechnic charge.

- Several incidents have been documented worldwide where airbags have been deployed during extrication operations or where stored gas inflators have been accidentally cut.

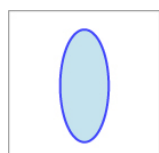


Figure 41: Airbag equipment of the Mercedes-Benz A-Class. A driver airbag, a driver knee airbag, a passenger airbag as well as front and rear seat-mounted side airbags are visible along the curtain airbags in the roofline. (Courtesy of Daimler)

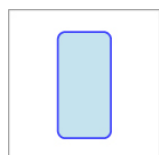


Note:

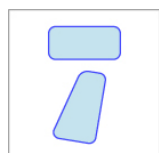
The location of airbag modules and remote inflators are indicated in the CRS diagram using the following symbols:



Driver airbag



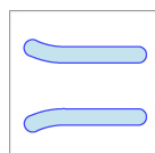
In dashboard:
Passenger airbag
In seat:
Anti-submerging Airbag



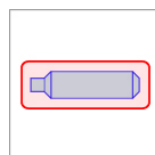
Side impact airbag (seat)
Far-side side impact airbag



Side impact airbag (side)



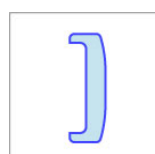
Curtain airbag
Head impact airbag



Stored gas inflator
(for curtain airbags)



Knee airbag driver



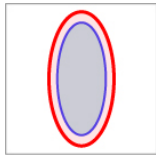
Knee airbag passenger

- Some airbags, especially from the early days of airbag development may be purely mechanical. **Mechanical airbags** do not utilize the vehicles electrical system to activate the inflator and can therefore not be disabled.
- Certain adaptive (**dual stage**) airbags may only fire one of the inflator stages to deploy the airbag. A remaining stage poses a hazard to emergency responders. Normally deployed airbags are not dangerous. However in case of an adaptive airbag with a remaining active stage special precautions should be taken.



Note:

Mechanical airbags or adaptive airbags where certain stages remain active following the deployment are marked with a red danger zone around the airbag symbol. Refer to the interactive background information to find out which type is involved.



Mechanical airbag
Dual stage airbag

4.3. Seatbelt pretensioners

- The function of a seatbelt pretensioner is to tighten up any slack in the belt in the event of an accident in order to link the occupant to the vehicle's deceleration as early as possible. Whereas the conventional locking mechanism in a retractor keeps the belt from extending further, the pretensioner actually pulls the seatbelt back.
- Seatbelt pretensioners can either be mounted on the retractor mechanism to spool the belt up or they may be mounted on the seatbelt buckle or the attachment point of the lap belt to pull the seatbelt back. There may also be multiple pretensioners per seatbelt. Most popular designs today use pyrotechnics to pull in the belt webbing.

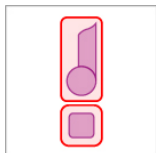


Figure 42: Drivers seat with seatbelt. The seatbelt pretensioner can either be mounted on the retractor, the seatbelt buckle or the lap belt anchor. In this case a pretensioner is mounted on the lap belt anchor and the seatbelt buckle. (Courtesy of Renault)

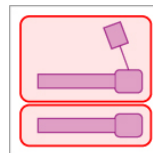


Note:

The locations of seatbelt pretensioners are indicated in the CRS diagram. The actual shape of the symbol may vary to better represent the actual form and size.



Seatbelt pretensioner
(Retractor)



Seatbelt buckle or lap belt
pretensioner

4.4. Rollover protection systems

- Rollover protection systems are used on convertible or retractable hardtop vehicles. They are designed to flap- or pop-up from behind the rear seat in case the vehicle rolls over, thus maintaining enough survival space for the occupants. Rollover protection system work in conjunction with the reinforced A-post.
- Most rollover protection systems are deployed by a pre-tensioned spring and are therefore easily reversible. This is why they may not only deploy in rollover accidents but also in other collisions recognized by the SRS control unit.

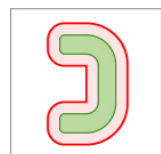


Figure 43: Rollover protection system of an Audi A4 convertible. The two automatic roll bars deploy behind the left and right rear seat. (Courtesy of Audi)



Note:

The location of automatic roll bars is indicated in the CRS diagram. The actual form of the symbol may vary to better represent the actual form and size.



Automatic roll bar

4.5. Handling restraint systems post-crash



Note:

When dealing with a vehicle equipped with restraint systems, the following points should be used as a general guideline:

- **Know what's inside**
- **Stay out of the inflation zone of undeployed airbags and rollover protection systems.**
- **Disable the restraint system.**
- **Avoid dangerous areas, especially inflators, pretensioners or restraint system electronics.**
- **Remove the seatbelt from the occupant if possible.**

Refer to **chapter 6** for additional emergency response procedures.

Know what's inside

- Knowing if the vehicle is equipped with restraint systems and where those components are located is essential when dealing with a modern vehicle.



Note:

The location of restraint system components is indicated in the CRS.

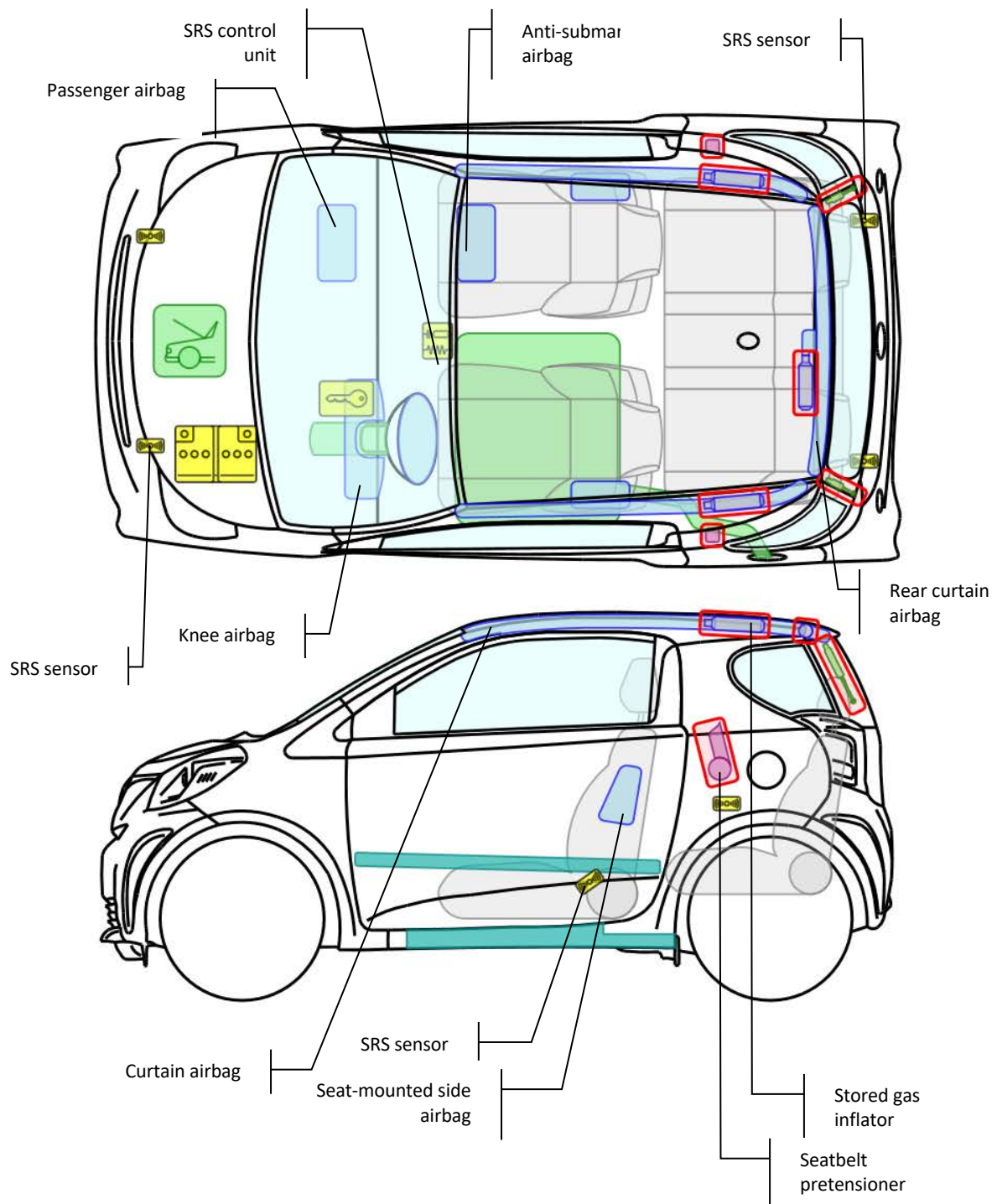


Figure 44: Restraint system components shown on a Toyota iQ.

5. Alternative propulsions

Note:

This chapter uses electrified vehicles (xEVs) as an example. xEV refers to any electrified propulsion system vehicle with a high voltage system, such as hybrid vehicles, plug-in hybrid vehicles, electric vehicles or electric vehicles with extended range.

This chapter only contains general information on alternative propulsion systems. For a full overview of available propulsion systems and emergency procedures refer to: ***Emergency response to incidents involving vehicles with alternative propulsion.***

5.1. Safety considerations

- Vehicles with alternative propulsion systems are **generally safe!** Differences in the potential hazards caused by the alternative propulsion system have been addressed by the car manufacturers' engineers during development. However, there may be differences in handling these vehicles in an accident situation.
- Basically, engineers are following two principles for developing a safe propulsion system, even in the event of a collision:

Package safety

- Fuel tanks, gas tanks and high-voltage batteries are mounted in areas that are **normally not affected during most crash scenarios**. This is why they are often mounted in the area of the rear axle or in the center of the vehicle.
- Gas tanks as well as high-voltage batteries have **protective casing or are very rigid by design** and it's not easy to damage these components.
- On xEVs, getting in contact with electricity is an additional danger. Therefore high-voltage components are **shielded or insulated to avoid direct contact** under normal circumstances. Other than the 12 Volt electrical system, the high-voltage system is **galvanically separated from the vehicle body**.



Figure 45: Moderate overlap crash test of an Opel Ampera. The test revealed that all safety features worked as planned. The propulsion system has been shut down on accident detection; the high-voltage battery has not been affected by the crash. (Courtesy of EuroNCAP)

Shut-down

- Following a collision, the integrity of all propulsion system components cannot be guaranteed anymore. Therefore an **automatic shutdown feature** should shut the propulsion system down **based on a preset impact level**. In most vehicles the measuring result of the restraint system sensors are used to detect this level.
- An event notification signal is then sent out to **shut down the relevant propulsion system components**, such as the fuel pump on conventional gasoline or diesel vehicles. In case of an xEV the main contactors will be opened to disconnect the high-voltage battery from the high-voltage circuit.

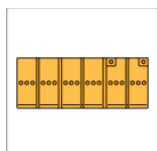


Figure 46: The image of this Toyota Yaris Hybrid clearly shows the location of high-voltage system components. The high voltage battery is located under the rear seat. Orange high voltage cables are routed under the floor of the vehicle to the engine compartment where they are connected to the electric motors and other high-voltage components. (Courtesy of Toyota).



Note:

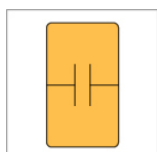
The locations of xEV components are indicated in the CRS diagram.



Battery pack



High voltage power cable



Ultra capacitor

5.2. Teaching points for xEVs

- An xEV may be **operational even if it is silent**.
- High-voltage power cables are bright **orange**, high-voltage components carry identification labeling.



Figure 47: Identification label for high voltage components

- Most xEVs are equipped with a high-voltage battery as well as **one or more conventional 12 Volt batteries**.
- The **high-voltage system and the 12/24 Volt electrical system** may be connected to each other by means of an electric converter, producing 12/24 Volt derived from high-voltage as long as the vehicle is switched on.
- Therefore disconnecting the 12/24 Volt electrical system may neither disable the high-voltage nor the 12/24 Volt circuit if the vehicle is switched on (ignition switch or power button on).
- An automatic shutdown feature should shut the propulsion system down based on the detection of a preset impact level. **A deployed airbag is an indicator, that the vehicle has been able to detect the collision.**
- However, as not all vehicles are equipped with such a shut-down feature and not all collisions can be detected or will result in airbag deployment, responders should **always assume the high-voltage battery and associated components are energized and fully charged**.
- Emergency responders should always take action to **manually disable the propulsion system**. The propulsion system can most likely be disabled by switching off the vehicle's ignition **and** disconnecting the 12/24 Volt circuit. Some vehicles require additional action indicated by the Crash Recovery System. Alternative deactivation methods are vehicle specific and also covered by CRS.
- **Physical damage to the high-voltage battery or an ultra-capacitor** may result in immediate or delayed release of toxic and/or flammable gases and fire. Refer to "*Emergency response to incident involving vehicles with alternative propulsion*" for more information.



Figure 48: Severely damaged Honda Civic Hybrid following a collision with a tree. The deployed airbag indicates that the high-voltage system may have been shut-down when the vehicle has recognized that something has gone wrong (Shut-down). However always assume that high-voltage components are energized and fully charged. The high-voltage cables are clearly visible on the right side of the vehicle and can be identified by their orange colour. There is no obvious reason why it should be necessary to cut those cables. The high-voltage battery is located behind the rear seatback in this vehicle. It has not been damaged during the crash, underlining that vehicle manufacturers try to use safest possible places for those components (package safely).

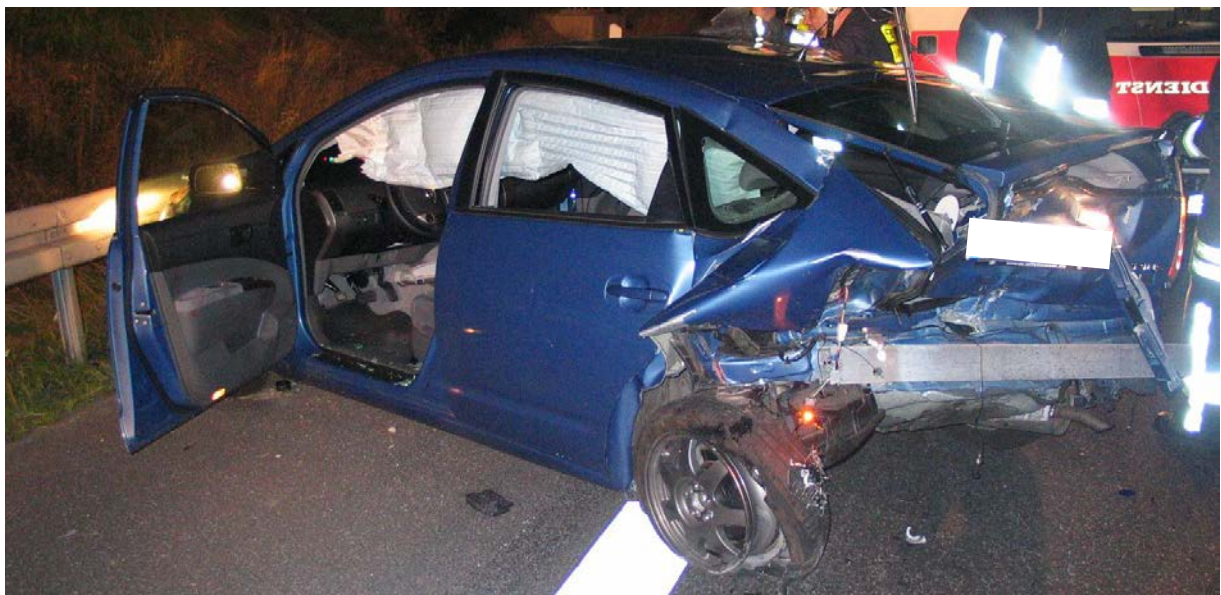


Figure 49: This Toyota Prius has been involved in a read-end collision. Again airbags have been deployed (which is not typical for this sort of collision) indicating that the high-voltage system may have been shut-down. However, looking at the vehicle shows that the headlights are still illuminated. If the high-voltage system has been disabled, this shows that xEV are normally also equipped with a 12 battery. Given that the ignition has not been switched off the restraint systems and associated sensors are still operational in this vehicle. (Courtesy of Feuerwehr Hofheim im Taunus)



Figure 50: This Toyota Prius has been involved in a rollover crash. No airbags have been deployed. Emergency responders should take action to manually disable the vehicle. It is important in such a case to switch off the vehicle's ignition and to disconnect the 12 Volt battery which is located in the trunk of the vehicle and easily accessible in this case. (Courtesy of Tipton Volunteer Fire Company)

5.3. Handling vehicles with alternative propulsion post-crash



Note:

When dealing with modern vehicles, the following points should be used as a general guideline.

- **Know what's inside**
- **Assess for gas release or battery/ultra-capacitor damage**
- **Immobilize the vehicle.**
- **Disable the propulsion system**
- **Avoid dangerous areas, especially high-voltage batteries and ultra-capacitors.**

Refer to **chapter 6** for additional emergency response procedures.

Know what's inside

- Knowing if the vehicle is equipped with an alternative propulsion system and where its relevant components are located is crucial when dealing with a modern vehicle.



Note:

The location of propulsion system components is indicated in CRS.

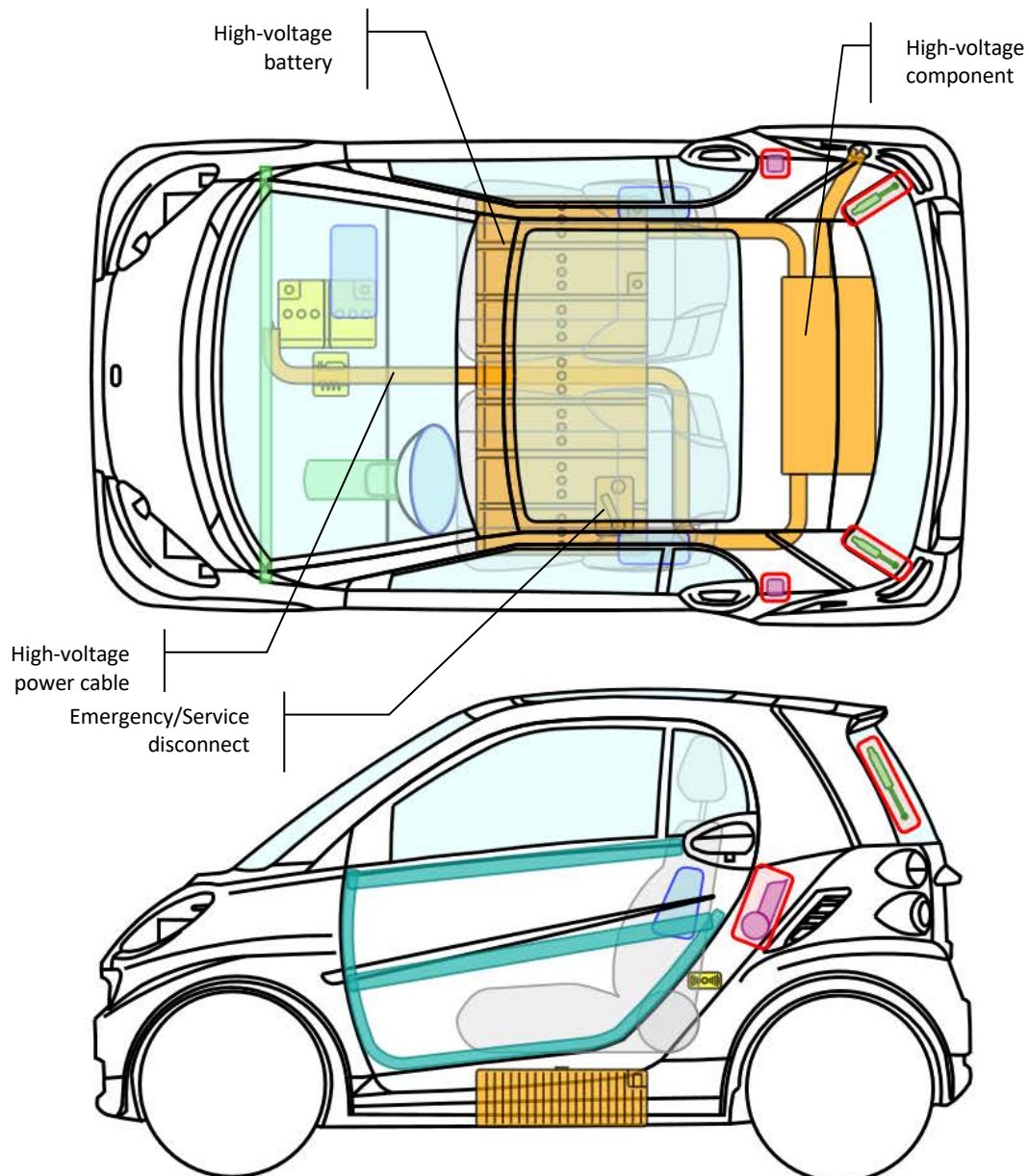


Figure 51: Propulsion system components shown on a Smart Fortwo ED (xEV).

6. Emergency operations

- One of the biggest challenges for the definition of emergency response procedures is to make them universal and applicable to all types of vehicles and propulsion systems. While this is certainly possible, it leads to a very extensive collection of procedures.
- The goal for emergency responders should be to obtain information about the relevant vehicle equipment and its propulsion system in the earliest stages of the incident. This knowledge may help reduce the delay caused by rescuers having to seek out this information
- The challenges related to modern vehicle technology can only be solved through an all-encompassing approach. In addition to the right tools it is very important to provide emergency response personnel with the necessary knowledge to deal with these vehicles. Vehicle specific information is provided by the Crash Recovery System.



Figure 52: All-encompassing approach to deal with modern vehicles.

6.1. General response procedure

- **Know what's inside.**
- **Assess for gas release or high-voltage battery and ultra-capacitor damage.**
- **Immobilize the vehicle.**
- **Keep out of the inflation zones of undeployed restraint systems.**
- **Disable the vehicle.**
- **Remove the seatbelt from the occupant if possible.**
- **Avoid dangerous areas.**
- **Don't mess around with heavy reinforcements!**

6.2. Know what's inside



Figure 53: Example incident from Venray (Netherlands). The involved vehicle has been retrofitted with LPG. Requesting the licenseplate also revealed this.

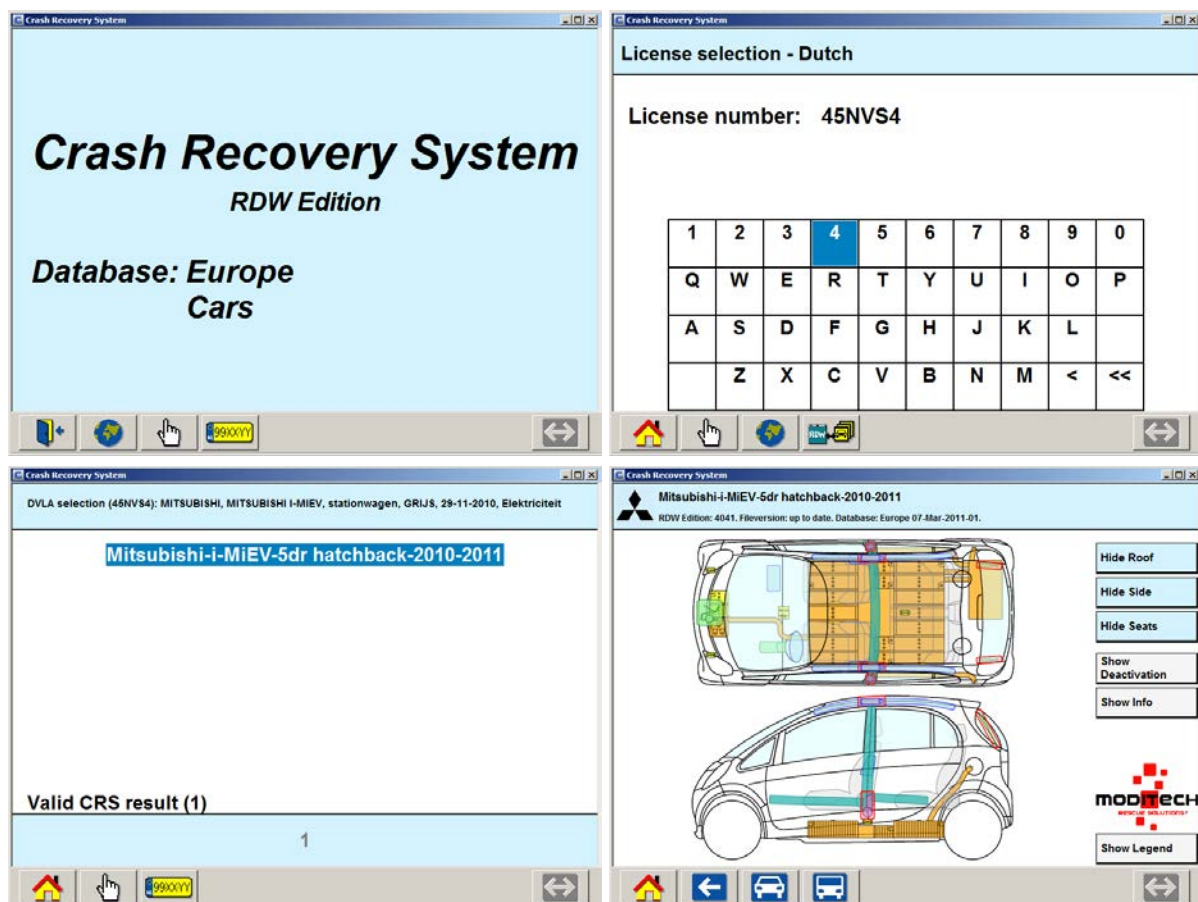


Figure 54: License plate request with the Crash Recovery System. The header in the lower left screenshots shows the result from the national database. In this case, it is a series produced electric vehicle, which has then been selected from the CRS database.

- There is no definite outside identification feature for motor vehicles with alternative propulsion!



Note:

The easiest and safest way to gather information about the propulsion system and the rescue relevant vehicle equipment is to request the license registration database with the Crash Recovery System using the vehicle's license plate number.

If the alternative propulsion system has been retrofitted to the vehicle, the Crash Recovery System is unable to provide technical information for the propulsion system. However, if the propulsion system is registered in the national license registration database, the type of propulsion will be shown in the request result!



Note:

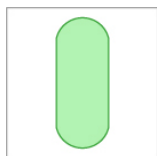
'Knowing what's inside' enables emergency responders to adapt stabilization measures and extrication techniques to the actual vehicle equipment and therefore improves overall safety and reduces the extrication time.

6.3. Assess for gas release or battery/ultra-capacitor damage

- Based on the type of propulsion used in the involved vehicle, emergency responders should assess the vehicle for relevant damage to the propulsion system components.
- In case of a vehicle powered by **CNG, LPG or hydrogen** a hissing sound, the odor of gas or ice-forming on **gas tanks** indicates a gas release.
- In case of an xEV an active smoldering, gurgling, bubbling, crackling and hissing or popping sound from the **high-voltage battery** indicates battery damage.
- Damaged **ultra-capacitors** may (depending on their voltage) also present a potential electrical shock hazard. The capacitors also contain the chemical acetonitrile as a solvent. Acetonitrile is highly flammable and harmful by inhalation, ingestion, and/or skin contact.

**Note:**

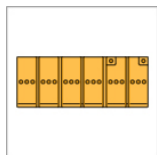
The location of gas tanks and safety valves as well as high-voltage batteries and ultra-capacitors is shown in the CRS schematic which may allow for a quick assessment.



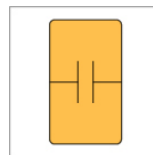
Gas tank
(CNG, LPG, Hydrogen)



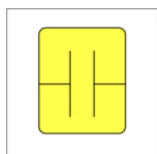
Safety valve



Battery pack



Ultra capacitor
(> 30 Volt)



Ultra capacitor
(< 30 Volt)

- If a high-voltage battery or ultra-capacitor is damaged or if there is release of gas, either from a CNG, LPG or Hydrogen tank, special measures are necessary.
- Refer to: “**Emergency response to incidents involving vehicles with alternative propulsion**” for further instructions.

6.4. Immobilize the vehicle



Note:

xEVs may be operational even if they are silent!

- **All** vehicles should be immobilized in an early stage of the incident to avoid unintended movement:
 - Block the wheels with wheel chocks
 - Shift the gearshift lever to „P“ (“Park“)
 - Apply hand brake/electronic park brake

6.5. Keep out of inflation zones of undeployed restraint systems



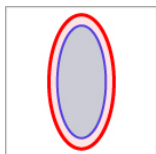
Figure 55: This graphic visualizes the necessary safety distances from any undeployed airbag. Emergency responders should stay 30 cm away from side and curtain airbags, 60 cm from the drivers airbag and 90 cm from the passenger airbag while working with rescue tool. (Courtesy of Audi)

- Emergency responders should be aware that working in close proximity of an undeployed airbag may pose a safety hazard. It is recommended to keep a safe distance from undeployed airbags at least when rescue tools are in operation.
- Depending on airbag sizes it is recommended to keep 30 cm distance from undeployed side and curtain airbags, 60 cm distance from an undeployed driver's airbag and 90 cm distance from an undeployed passenger airbag during operation of rescue tools.
- If an undeployed rollover protection system is present, rescuers will need to remain clear of the deployment path.
- Emergency responders should avoid placing objects on an undeployed airbag and undeployed rollover protection systems.



Note:

Deployed airbags are normally safe. In some airbag designs (especially with vehicles built for the North-American market) one stage of an adaptive airbag may remain active after activation. Such airbags are indicated in the CRS diagram. Keep in mind that the red danger zone around an airbag symbol can also indicate a mechanically deployed airbag.



Dual stage airbag

6.6. Disable the vehicle

- In order to allow emergency responders to work safely on a crashed vehicle, **all systems, including propulsion system, restraint system and electrical system should be disabled** as much as possible.
- Treat the vehicle as being a machine. In a machinery entrapment situation, disabling the machine is one of the steps with the highest priority.

1. Switch the ignition switch or power button to off.

Note:

Switching the vehicles ignition switch or power button to off will normally:

- Disable the propulsion system, for instance by switching off the engine or the fuel pump, closing of gas tank valves and/or interrupting the high-voltage circuit.
- Switch of the power supply to the SRS control unit and the SRS sensors, therewith initiating the drain time of the capacitors.
- Prevent the vehicle from being inadvertently started, for instance when moving the vehicle.

Note:

Before disabling the vehicle, **consider using electrical systems such as the steering column adjustment, seat adjustment, electrically powered windows, etc.**

- To switch off the ignition switch, the ignition key should be rotated to the “off” position. On vehicles with electrical seats and electrical steering column adjustment it is recommended to leave the key in place. On some vehicles the seat and steering column will move immediately after the ignition key is removed.

2. Disconnect the 12/24 Volt electrical system of the vehicle.

Note:

Disconnecting the vehicles 12/24 Volt electrical system will normally:

- Reduce the risk of a post-crash fire by preventing short-circuits.
- Reduce the dangers of an accidental deployment of restraint systems due to short-circuits.
- Prevent accidental system restart.
- Switch off the air suspension system (buses and coaches) to enable safe lifting of the vehicle.



Note:

Mechanically activated restraint systems components cannot be disabled by switching the ignition switch or power button to off and disconnecting the 12 Volt electrical system.

Note:

The **exterior hazard lights** can be used as an indicator for an active 12/24 Volt electrical system. If you have disconnected a battery and the exterior hazards lights are still on this is an indicator that a second battery is located in the vehicle.

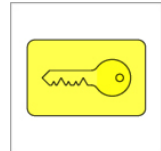
Switching the power button to off

- Some vehicles do not utilize a conventional ignition key. These vehicles can generally be started and disabled with a power button. **The power button is located on the dashboard or around the gearshift lever.** In order to start the vehicle, an electronic transponder key fob needs to be in the interior of the vehicle.



Note:

The presence of an (optional) power button is indicated in the CRS diagram.



Start/Stop Button
Engine stop

- To switch the vehicle off the **start/stop-button needs to be pushed once**. Make sure the brake pedal is not pushed when using the start/stop-button.

Note:

When the power button is switched off, pushing it again may inadvertently switch on the vehicle. This is why it is important to **check the status of the ignition** before pushing the button.



Figure 2: Start/stop-button, shown on a Toyota Prius

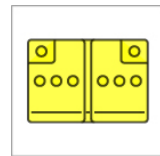
- To prevent the system from being inadvertently restarted, the electronic transponder key fob should **be removed at least 5 meters from the vehicle** if easily possible. Disconnecting the 12/24 Volt battery will also ensure that the ignition cannot be activated again.

Information on disconnecting the battery

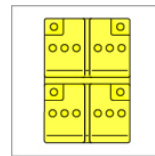
- The location of the 12/24 Volt battery varies from vehicle to vehicle. It can be mounted in the engine compartment, in the wheel well, somewhere in the trunk of the vehicle, under front or rear-seats or under the floor.
- Some vehicles utilize more than one 12 Volt battery for the 12 Volt electrical system. Heavy trucks, busses and coaches normally use two 12 Volt batteries connected in series for their 24 Volt electrical system.

**Note:**

The location of the 12/24 battery/batteries is indicated in the CRS diagram. CRS will also indicate if more than one battery exists in the vehicle.



Battery (12 V)



Battery (24 V)

**Note:**

If necessary CRS will indicate how to gain access to the front or rear compartment

Engine hood opening
(rear hinges)

Trunk lid opening

**Note:**

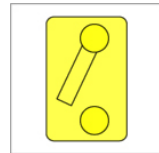
CRS interactive background information may support responders with hints to get to the battery or to an external disconnection point.



Figure 3: The 12 Volt battery of this Volkswagen Touareg Hybrid is located under the driver's seat. The negative battery cable can be disconnected from the vehicles body on the ground point in front of the driver's seat. This ground point is accessible through a flap in the carpet. The Crash Recovery System contains all information for the cable disconnection procedure.

**Note:**

Heavy trucks, buses and coaches are often equipped with a main battery switch to interrupt the 24 Volt circuit. Using the main battery switch is often faster and easier than disconnecting the batteries and therefore recommended. The location of the main battery switch is indicated in the CRS diagram.



Main battery switch

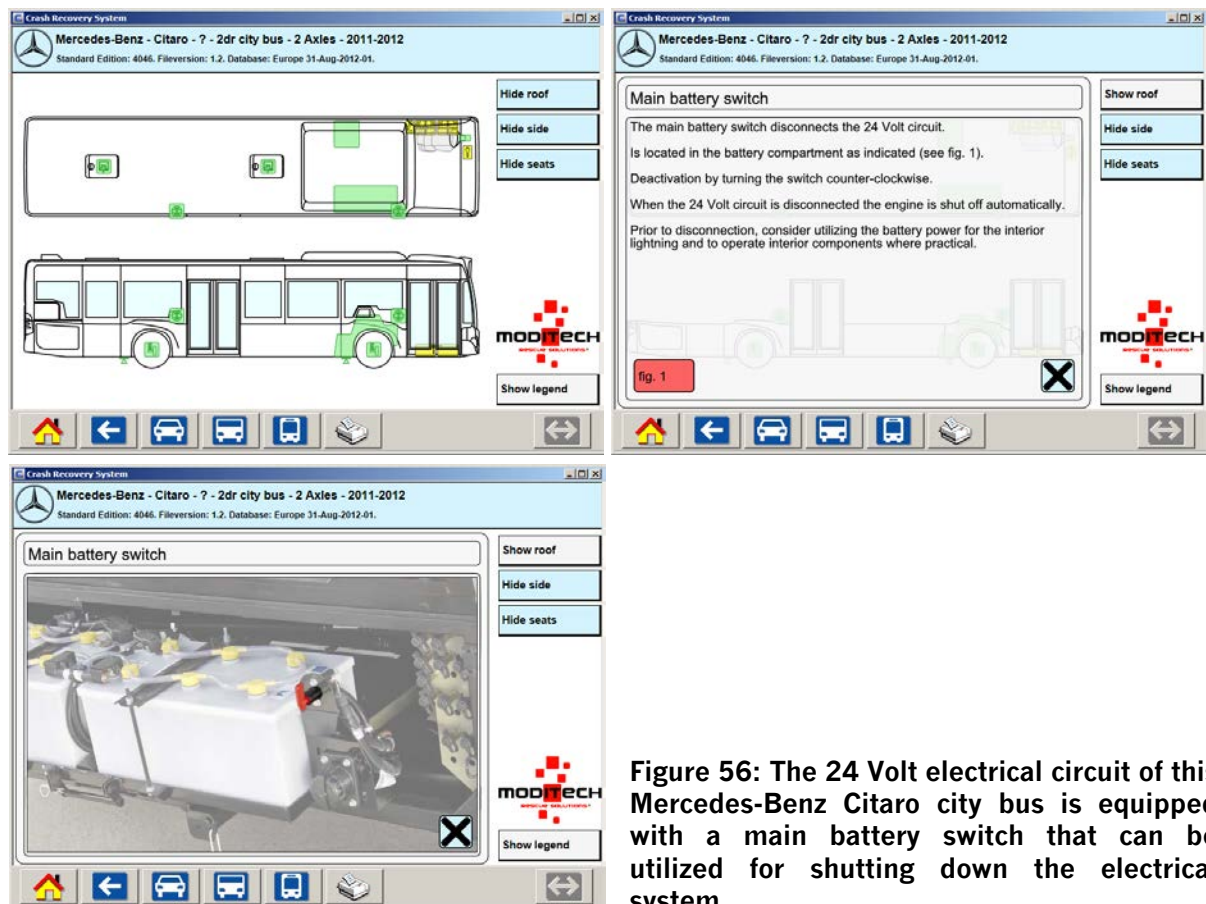


Figure 56: The 24 Volt electrical circuit of this Mercedes-Benz Citaro city bus is equipped with a main battery switch that can be utilized for shutting down the electrical system.

Disabling the 12/24 Volt and high-voltage electrical system on xEVs – Primary method



Note:

In order to disable an xEV some vehicle manufacturers require more disabling steps in addition to switching the ignition switch or power button to off and disconnection of the 12/24 Volt electrical system..



Note:

Step-by-step instructions on how to disable the vehicle can be obtained from the Crash Recovery System deactivation information.

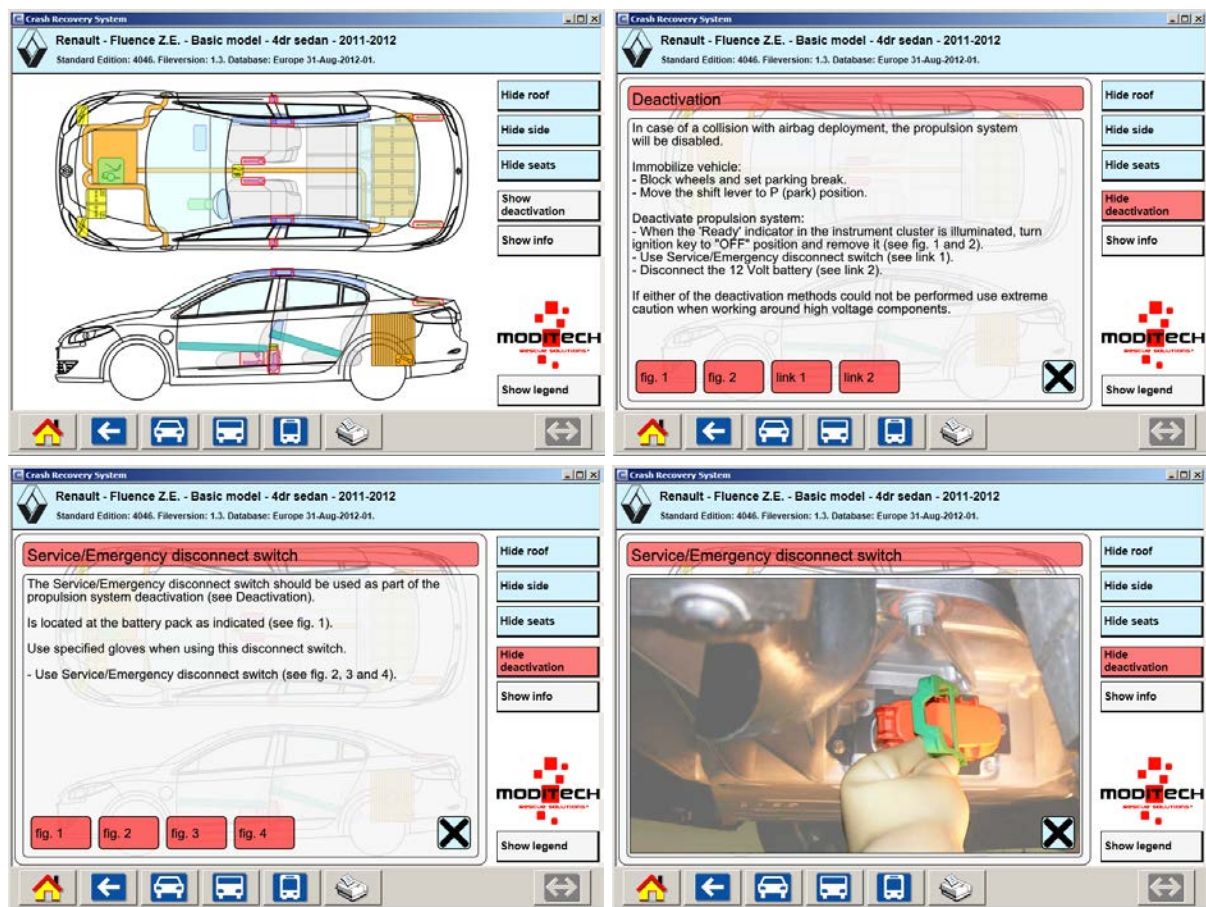


Figure 4: In addition to switching the ignition switch to off and disconnecting the 12 Volt battery, a service/emergency disconnect switch needs to be removed on this Renault Fluence Z.E. The location of the service/emergency disconnect switch is indicated in the CRS diagram. Note, that the manufacturer requires suitable PPE (insulated glove) to remove the service plug.

Disabling the 12/24 Volt and the high-voltage electrical system on xEVs – Alternative method



Note:

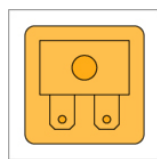
On xEVs, **disconnecting the 12/24 Volt electrical system may neither disable the high-voltage nor the 12/24 Volt circuit** if the vehicle is switched on (ignition switch or power button on).



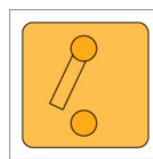
Note:

In case the ignition switch or power button is not accessible, CRS will provide an alternative method to disable the high-voltage system for most vehicles.

The location of primary or alternate components required to disable the high-voltage system is indicated by the following symbols:



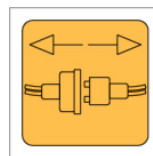
Emergency disconnect
(Remove fuse)



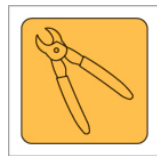
Emergency disconnect
(Use switch)



Emergency disconnect
(Use service plug)



Emergency disconnect
(Separate cable connection)



Emergency disconnect
(Cut cable)



Emergency disconnect
(Unscrew connection)



Emergency-off switch

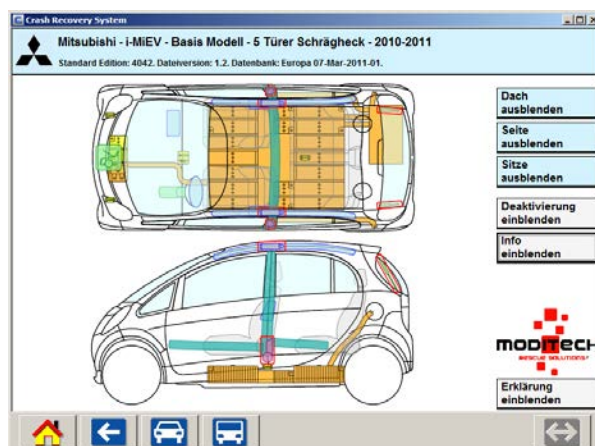




Figure 5: If the ignition key of this Mitsubishi i-MiEV (Electric vehicle) is not accessible, a certain fuse from the fuse box needs to be removed and the 12 Volt battery needs to be disconnected to completely disable the propulsion system.

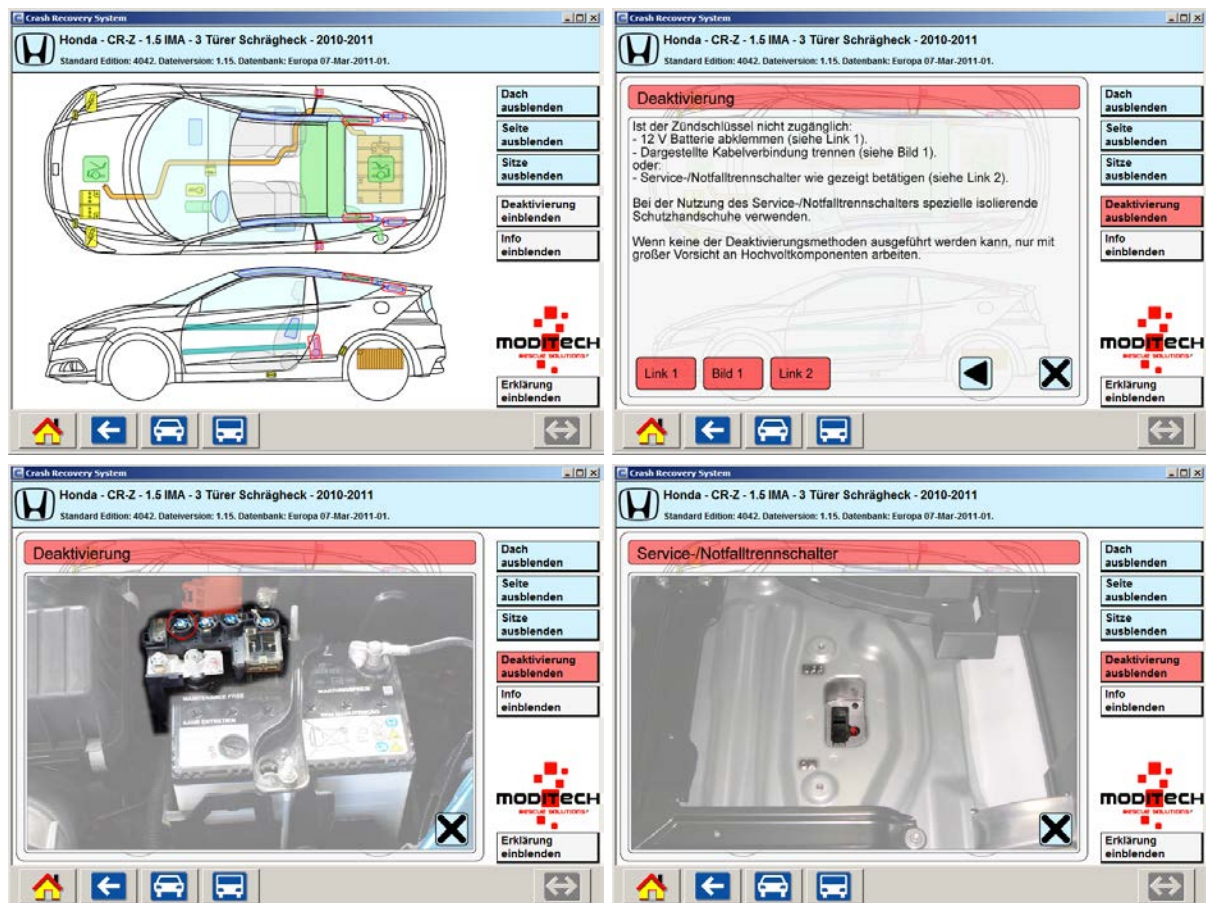


Figure 6: If the start/stop button of this Honda CR-Z (mild hybrid) is not accessible, an additional cable connection needs to be removed or the service disconnect switch needs to be operated.



Note:

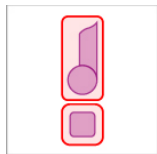
As long as the ignition switch or the power buttons are switched to on, some of the alternate disabling procedures will only disable the high-voltage circuit. The 12/24 Volt electrical system and the restraint system may remain active

6.7. Remove the seatbelt from the occupant if possible

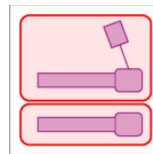
- While the deployment status of airbags can easily be identified, it is more difficult to find out if seatbelt pretensioners have already been deployed. This is why the seatbelt should be removed from the occupant in an early stage of the response if the scenario allows it. This ensures that an accidental deployment of the seatbelt pretensioners will not affect the occupant.

**Note:**

The presence and exact location of seatbelt pretensioners is indicated in the CRS diagram.



Seatbelt pretensioner
(Retractor)



Seatbelt buckle or lap belt
pretensioner

6.8. Avoid dangerous areas

- Even if the vehicle's systems (propulsion system, restraint system, etc.) have been disabled, certain components **should not be damaged for any reason** during extrication.



Note:

Every vehicle is equipped with components, which should better be avoided during emergency response operations, such as airbag modules, stored gas inflators, seatbelt pretensioners, fuel tanks, but also high voltage batteries, high voltage power cables, gas tanks and gas lines. The CRS diagram indicates the **exact location** of those components.



Note:

If the vehicles 12/24 Volt electrical system and/or the high-voltage electrical system cannot be disabled, also keep away from restraint system electronic components (SRS sensor, SRS control unit).

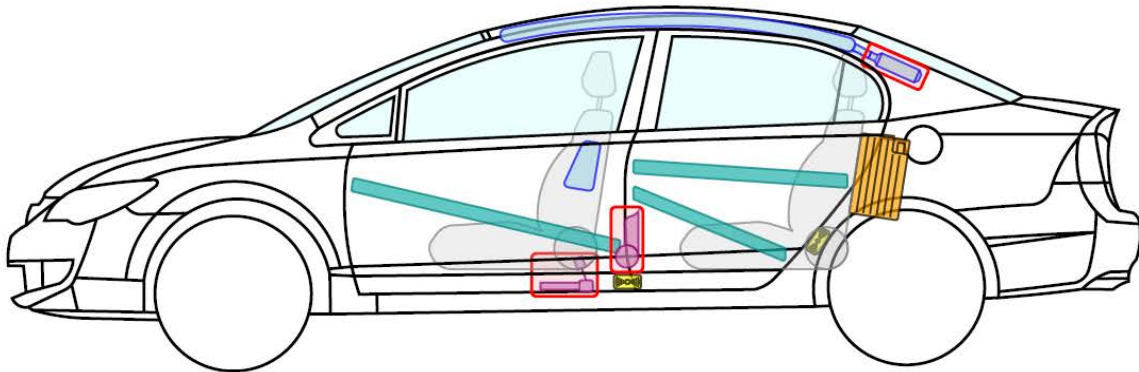


Figure 7: Honda Civic Hybrid, the high voltage battery is located behind the rear seat and should not be damaged for any reason. This also applies to the stored gas inflators of the head impact (curtain) airbags or the seatbelt pretensioners. Tool evolutions like tunneling through the trunk will be difficult to accomplish due to the high-voltage battery.

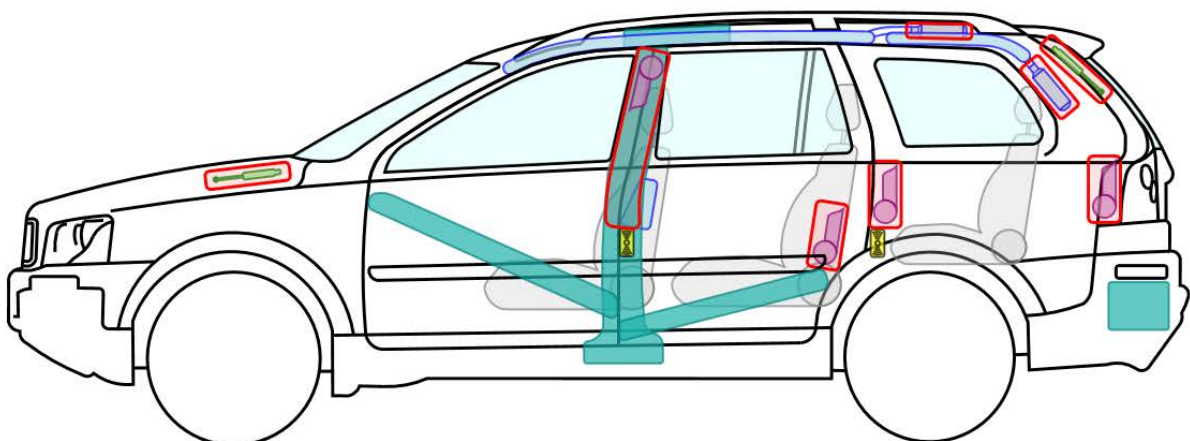
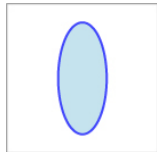


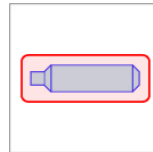
Figure 8: This Volvo XC90 is equipped with numerous restraint systems. In addition the B-post is reinforced. This all needs to be taken into account when performing tool evolutions such as a total roof removal. Stored gas inflators and seatbelt pretensioners should be avoided together with the cylinder for the rear hatch mounted to the D-post.

**Note:**

Airbag modules are indicated in the CRS diagram by a blue color. Airbag modules normally also contain an inflator, which should not be damaged for any reason.



Driver airbag

Stored gas inflator
(for curtain airbags)**Note:**

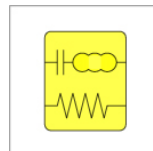
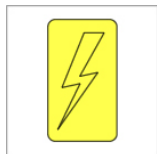
Stored gas inflators are only shown in Crash Recovery System if they are mounted remote from the airbag itself. Airbag modules (such as a driver airbag) always contain an inflator. The module should not be damaged even if no inflator is shown!

**Note:**

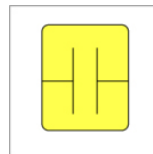
Electrical components of the vehicle are active as long as the vehicle's low and high-voltage systems have not been disabled.



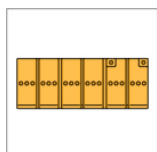
Sensor front / side

SRS control unit
Roll bar control unit

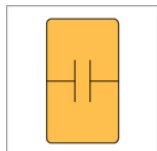
Xenon lights

Backup power-supply
Ultra capacitor**Note:**

High-voltage battery packs and ultra-capacitors will keep their electric potential. High voltage components and cables should be avoided, even after successfully disabling the system.



Battery pack

High voltage power cable and
components

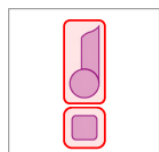
Ultra capacitor

**Note:**

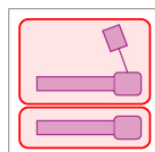
High voltage power cables are equipped with an orange insulation for easy identification.

**Note:**

In addition to removing the seatbelt from the occupant, seatbelt pretensioners are mostly pyrotechnical devices that should not be damaged when possible.



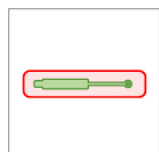
Seatbelt pretensioner
(Retractor)



Seatbelt buckle or lap belt
pretensioner

**Note:**

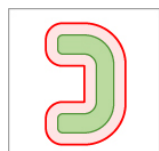
Some additional components should also be taken into consideration while working on the vehicle. The Crash Recovery System indicates the location of those components:



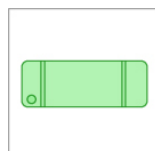
Cylinder to support engine
hood or trunk lid



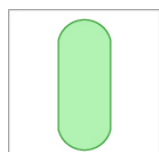
Fuel tank



Automatic roll bar



Truck fuel tank



Gas tank
(CNG, LPG, Hydrogen)



Safety valve

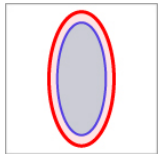
Mechanically activated restraint systems

**Note:**

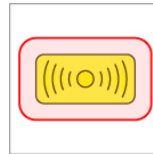
Mechanically activated restraint system components cannot be disabled by switching the ignition switch or power button to off and disconnecting the 12 Volt electrical system.

**Note:**

Mechanically activated restraint system components are indicated in the CRS diagram.



Mechanical airbag



Sensor front/ side (mechanical)

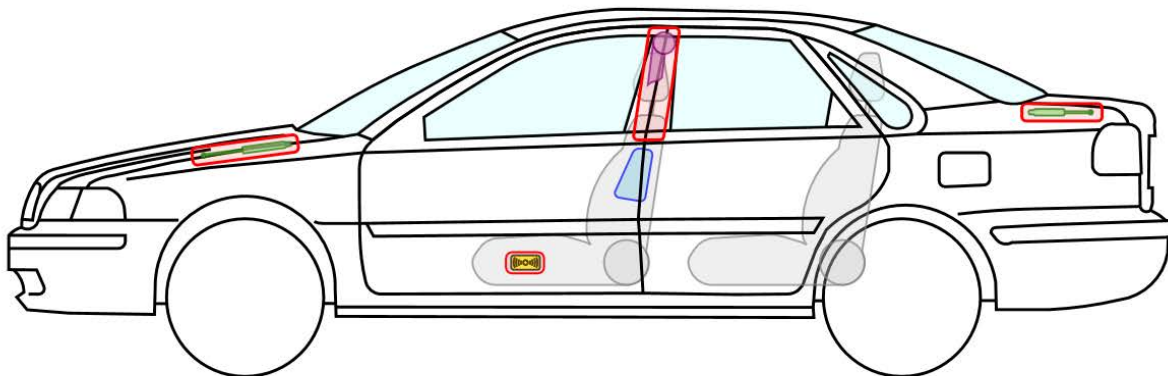


Figure 57: This Volvo S40 is equipped with a mechanically activated side airbag. The sensor is located in the seat and visible from the CRS diagram. It cannot be disabled by switching the ignition switch off and disconnecting the 12 Volt electrical system.

- Mechanically activated airbags and sensors do not work with the SRS control unit. In the case of the Volvo shown above each side airbag is a self-contained mechanical (non-electrical) pyrotechnic system consisting of the airbag module, the sensor unit and the pyrotechnic firing circuit. The mechanical sensor unit contains a small detonation cap that is triggered by the penetration of the vehicle structure, starts the inflation process by sending a pyrotechnic flash to the side airbag module.

6.9. Don't mess around with heavy reinforcements



Note:

The CRS diagram will also indicate the location of heavy reinforcements. Refer to chapter 3 for additional information.



Reinforcement

7. Training suggestions

- It is particularly challenging to include modern vehicle technology and vehicles with alternative propulsion into practical training evolutions. However, the including simulations in practical training will ensure that theoretical knowledge will be used in everyday response operations. If the training session include practical exercises on the extrication process and teamwork, it is possible to simulate the old car from the junkyard is a new vehicle with a little bit of preparation.
- To do this, select a late-model vehicle from the CRS and prepare the old training vehicle with airbag IDs and batteries according to the vehicle information supplied in the CRS.

7.1. Apply airbag labels



Figure 9: Simulated airbag label on the upper part of a B-post



Figure 10: Simulated deployed driver and passenger airbags

- Airbag locations can be identified with labels or stickers containing words labels like Airbag, SRS or IC (Inflatable Curtain). It is also possible to prepare the vehicle with already deployed airbags. Just cut out the bag of an already deployed airbag and place it in the old vehicle, to

simulate the presence of a deployed passenger airbag. It is very easy to pinch the bag in the glove box of the old vehicle.

7.2. ,Build in‘ a battery

- The battery magnet from the Moditech magnetic label set can be used to simulate the existence and location of a battery in the vehicle, even if the real battery has already been removed. Because of the small thickness of this battery dummy it is possible to place the "battery" under seats or under the trunks floor mat. When performing extrication training, the vehicle's battery should always be disconnected as part of the vehicle preparation.



Figure 11: Dummy battery in the trunk of a vehicle

7.3. Simulate an alternative propulsion system

- Another idea is to give the vehicle some of the characteristics of an alternative fueled vehicle in order to visually train emergency responders in the awareness and identification of hybrid components. One possible option is to attach some orange colored 'high voltage' power cable to the floor of the vehicle. Hybrid "labels" can be attached in normal label areas as well.



Figure 12: Simulated high voltage power cable on the underbody of a vehicle

7.4. Allow vehicle identification

- During the training drill, emergency responders should be able to identify that the vehicle they are working on is "brand-new", either by locating hints on the vehicle itself or by verbal information from the training officer. It is possible to allow a manual selection within the CRS by adding brand logos and model designations to the vehicle. This can be done by writing a make/model on the vehicle with a marker pen.
- In countries where the vehicle can be selected by entering the license plate number or the vehicle identification number it is possible to place these numbers on the vehicle.
- A license plate magnet can be used in the front and rear of the vehicle to allow for quick identification of the vehicle. The magnet can be labeled with the desired license number using a board marker.



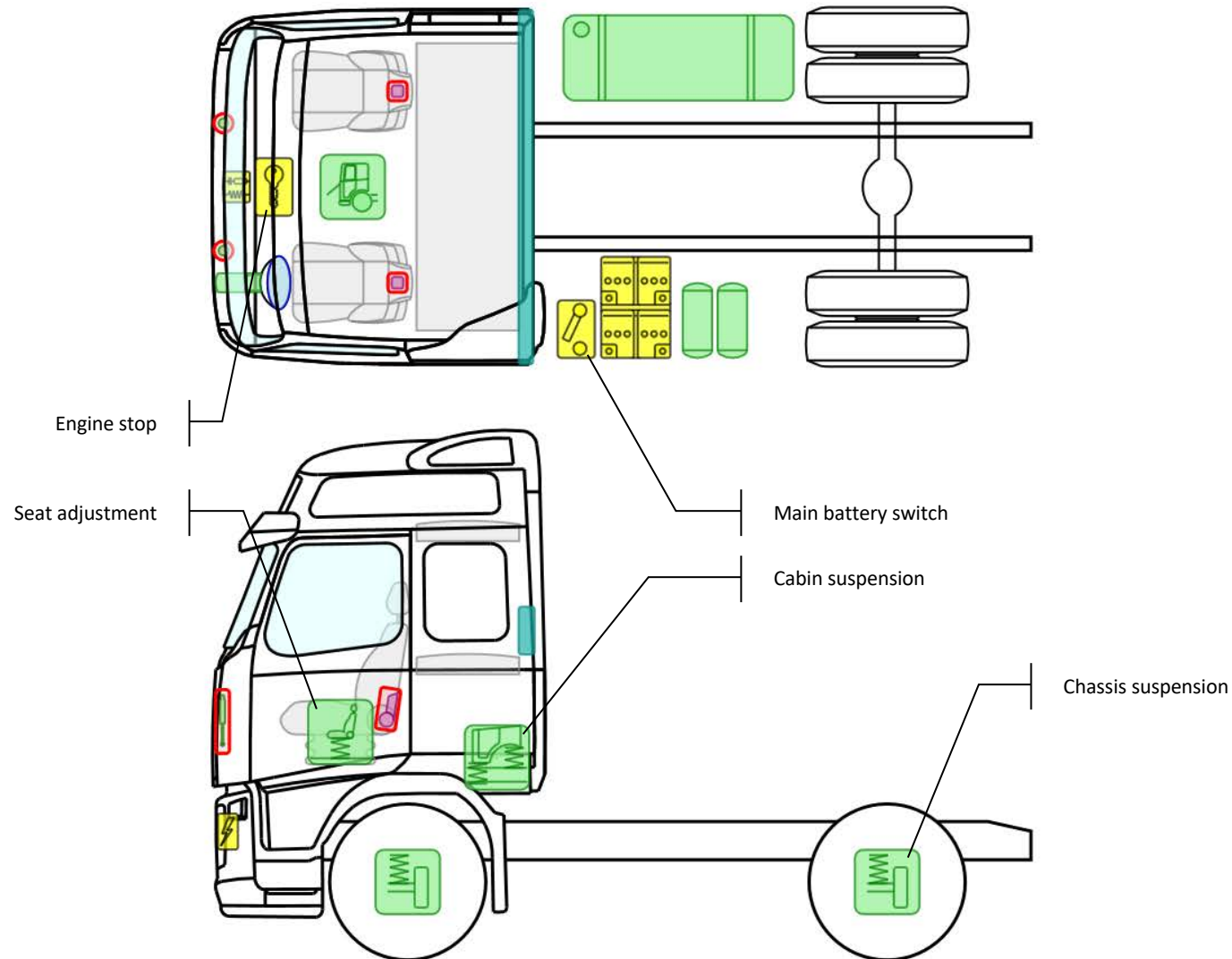
Figure 13: License plate magnet

- A sticker with the desired VIN can be placed in the edge of the windshield or in the doorframe to allow identification.

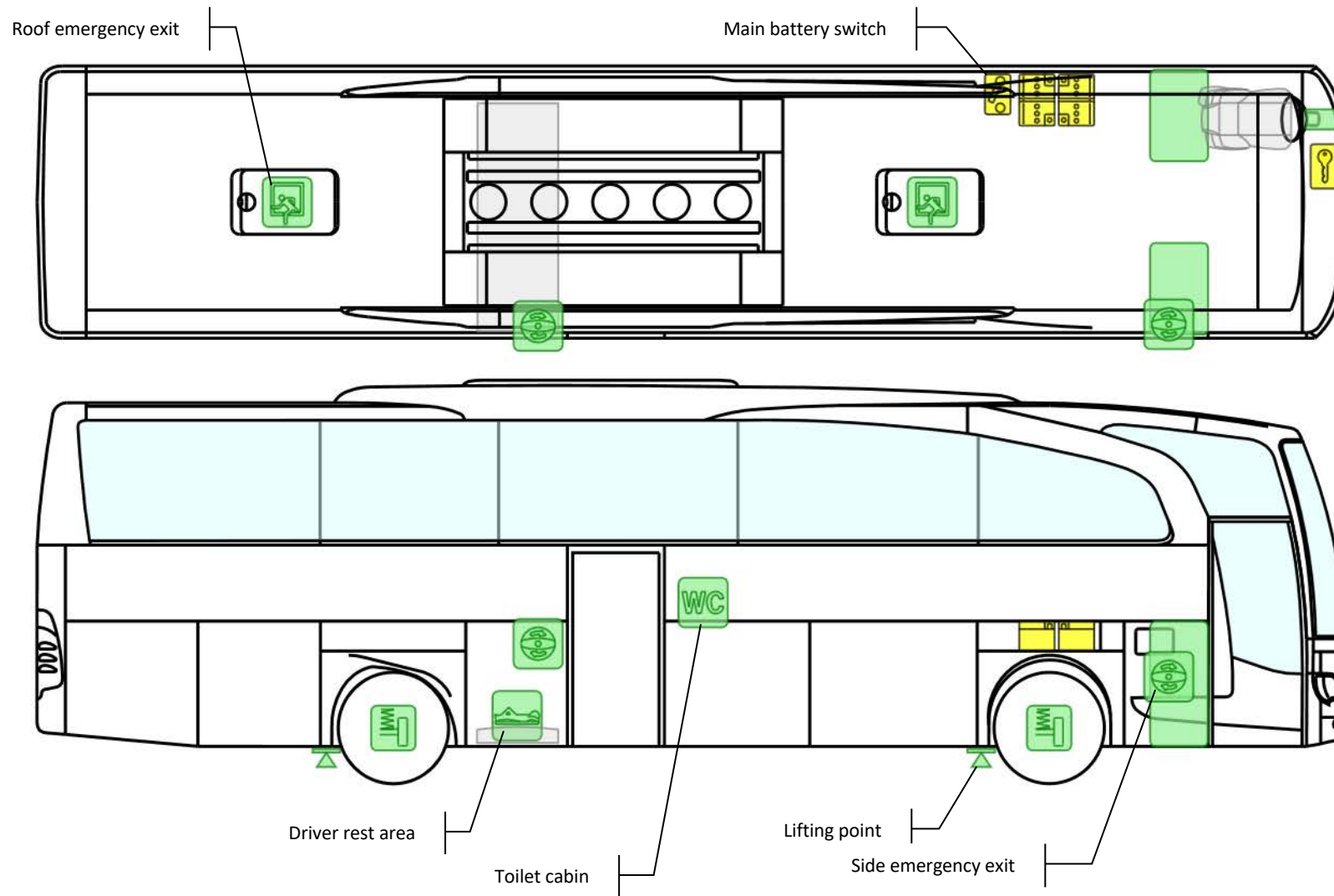


Figure 14: VIN-Label

8. Know what's inside – Truck information



9. Know what's inside – Busses and coaches



Have You Properly Secured the Vehicle?

Proper disabling of modern road vehicles...



Figure 1: How do you know if you have secured all the hazards with any vehicle that is involved in a collision? (Courtesy of wiesbaden112.de)

Emergency services around the world are routinely called to motor vehicle collisions, and the number and diversity of motor vehicles that rescuers are called to deal with is increasing. In the past, the vast majority of cars were fueled with either gasoline or diesel fuel, and other than fuel leaks, the biggest concern rescuers were taught to deal with was disconnecting the 12-volt battery to make the vehicle “safe”. This was taught as a way to control/deplete the stored energy related to frontal airbag systems and to reduce the risk of post-crash fires. Rescuers were reasonably assured that the vehicle was disabled if this activity was completed.

However, in the case of today’s alternative energy system vehicles just securing the 12-volt battery may be totally inadequate. Changes in propulsion systems have given us “silent cars”, potential high-voltage component hazards, and any number of additional never-seen-before hazards that rescuers are only beginning to learn how to respond to. These propulsion systems, coupled with the increasing number of supplemental restraint systems, and the use of higher strength steels may make it difficult for rescuers to be able to provide for an expeditious extrication of injured victims. It is imperative that rescuers be aware of these changes and know what is inside the vehicle they are dealing with.



Figure 2: The electrically powered parking brake control in the 2012 Buick LaCrosse.

Today, keeping all of these concerns in mind, if rescuers follow a few simple and straightforward steps at the beginning of the extrication process, they can be reasonably assured that the vehicle will be safe to perform appropriate extrication activities in a timely and safe manner. These steps need to be in the form of a systematic approach to vehicles involved in collisions that rescuers incorporate into their daily response activities.

When we say systematic, we mean approaching every vehicle in every accident the same way. This systematic approach is something that agencies should consider incorporating into their standard operating guidelines for motor vehicle collision response. So how and why should rescuers follow a step-by-step process?

Let us begin with initial scene size-up and stabilization. Rescuers need to begin by establishing appropriate incident command, safety and hazards zones, and completing a 360-degree assessment. As part of this initial assessment, rescuers should immediately place wheel chocks fore and aft at each vehicle within the 50 foot/15 meter radius safety area. This will begin to immobilize the vehicle and prevent any possible movement.

The rescue crew should then begin to immobilize the vehicle itself by activating the parking brake. This may be as simple as pulling a lever or stepping on a pedal, but more and more vehicles are using an electric parking brake mechanism. This is activated using a button that is usually located in the area of the transmission shift lever (see fig. 2). This must be completed prior to disconnecting the vehicle's power supply since it is an electric-powered mechanism.

The next action should be to place the vehicle's transmission in "park" if possible. There may be instances where the transmission shifter linkage is damaged and may not permit this, but the rescue crew should attempt to get the vehicle into "park" or at the very least "neutral". Rescuers will then want to secure the ignition by either turning off the key or pushing the ignition button (see fig. 3). Operating an ignition button is slightly more difficult than a traditional ignition key because the status of the ignition is not obviously visible. If the occupant or a bystander has already switched off the ignition, it is certainly possible to activate the car again by pushing the button. This is why car manufacturers advice also includes checking the 'Ready-Indicator' somewhere on the dashboard of the vehicle.

Vehicle manufacturers also advise rescuers to remove the key or key fob from the vehicle. The reason for this advice is to avoid accidental restart of the vehicle. Therefore no time should be wasted to search for a key or key fob if it is not obviously visible in the vehicle as smart key systems may also be carried everywhere in the interior (drivers pocket, handbag etc.). As soon as the deactivation process is complete, accidental restart of the system is not possible anyway.



Figure 3: Ignition button on a 2012 Toyota Highlander Hybrid. These will be found on many vehicles, not just alternative power vehicles.

Shutting off the ignition of a vehicle is an often-underestimated safety factor. The fuel pump will stop to work, high voltage relays used on the high voltage batteries of hybrid- and electric vehicles will open, electromagnetic shut-off valves used on natural or propane gas tanks will close and the supplemental restraint system ("SRS") control unit will lose its power and the

drain time of the built-in capacitors will start. While some of those measures may already have been triggered by the SRS control module because of the crash detection it is important to manually switch off the ignition to make sure the systems are really disabled. Remember that not all sorts of accidents can be detected by the SRS system.

If the ignition cannot be switched off, just disconnecting the 12-volt battery will probably not disable a hybrid or electric vehicle. Research shows that even after disconnecting the 12-volt negative battery cable, there are vehicles that will remain powered if the ignition is still in the “on” position. The vehicle can actually be driven with the 12-volt disconnected. Two examples of vehicles that this will occur with are the Mitsubishi i-MiEV and the Chevrolet Volt (US) /Opel Ampera (Europe).

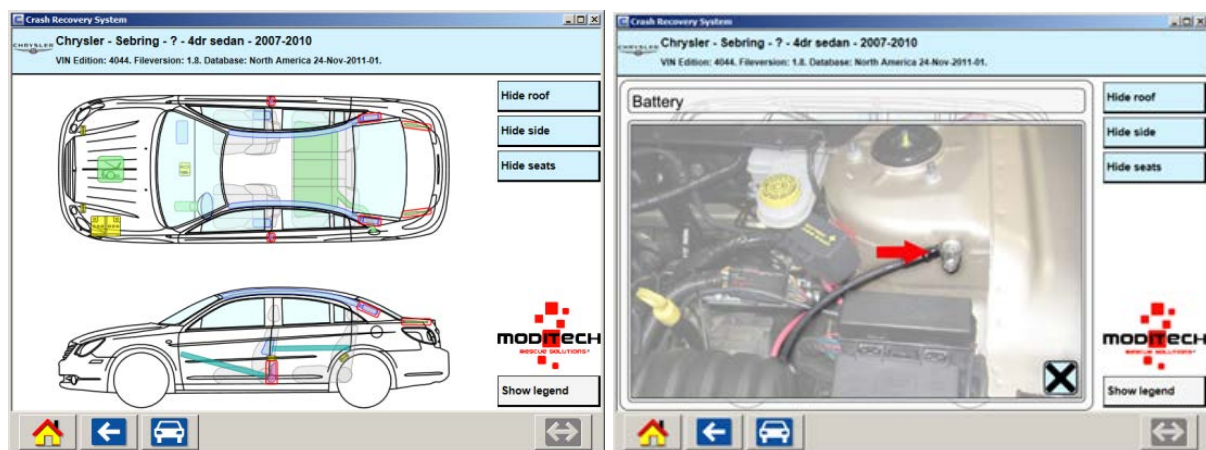


Figure 4: The 12-volt battery of this Chrysler Sebring is located in the wheel well of the vehicle. Accessing the battery is a challenge when the wheel is mounted and virtually impossible with crash damage. However, the battery ground cable can be disconnected

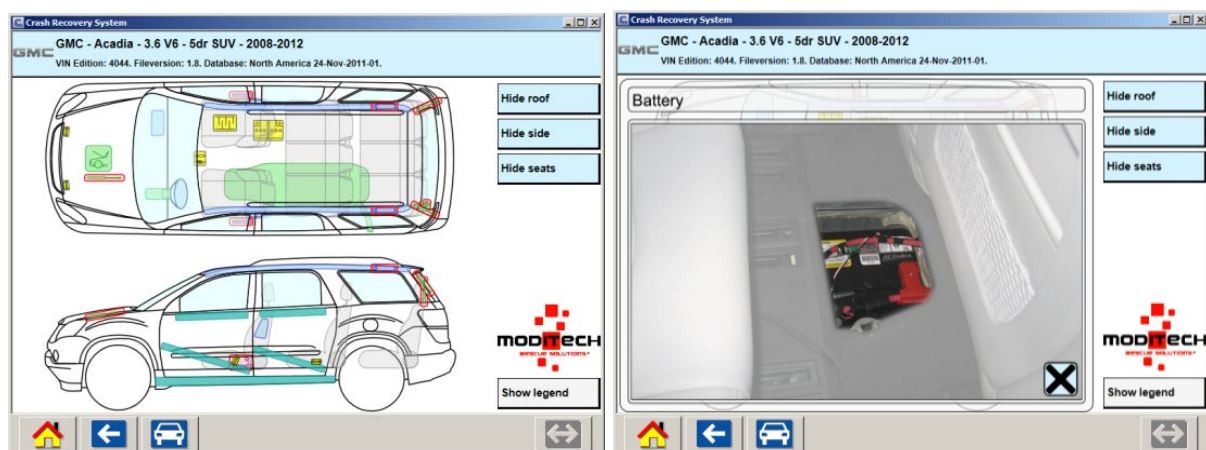


Figure 5: The 12-volt battery of this GMC Acadia is located in the floor of the vehicle under the passenger’s seat. The screenshots from the Crash Recovery System show how it can be accessed.

The reason for this is that, in the simplest of terms, the vehicle only needs its 12-volt battery to open the high voltage relays and after that, the vehicle is powered entirely from the high voltage battery pack. As long as the ignition remains “on” the vehicle is drivable and all systems including the SRS system are operational.

Rescue companies may also want to consider activating a vehicle’s four-way/emergency flashers as part of their initial vehicle assessment. This will give an indication of the status of the vehicle

and will serve as another method of determining that the vehicle has been de-powered, as well as alerting all rescuers on the scene to the status of the power supply. As stated previously, just because the 12-volt power supply is disconnected, does not mean the vehicle is de-powered. Many late model vehicles will activate the emergency flashers automatically when an accident has been detected. The described procedures only take few seconds and should be carried out before patient treatment should start inside the vehicle.

The next step should be to secure the vehicle's power supply, which may be connected to a conventional 12-volt battery or eventually a high-voltage battery. If the vehicle is only equipped with a conventional 12-volt system, the biggest challenge in respect to disabling is to locate the battery or batteries of the vehicle. This is why the incident commander may want to consider acquiring details about the vehicle equipment using a vehicle information system such as the Crash Recovery System (CRS). This system provides a detailed view of all rescue relevant vehicle equipment such as the battery, airbags, reinforcements and propulsion system components. The location of the 12-volt battery will be shown, as well as instructions on how to get to the battery will help emergency responders to even locate batteries that may be hidden in the trunk, under seats or in the wheel well of the vehicle (see fig. 4 and 5 for examples). The CRS also provides assistance in locating the battery ground cable if it can be accessed easier than the battery itself.

The difficulties in locating or accessing the 12-volt battery on late-model vehicles often leads to the discussion as to whether it is generally necessary to disconnect the vehicles power supply. The manufacturer's emergency response guides are quite clear in this respect and advise to do so. Being realistic, every emergency responder knows that there may be occasions when the battery cannot be accessed because of its location or the position of the vehicle. Nevertheless, remember that shutting down the vehicle is just as important for everybody's safety as with every other machine emergency responders have to work on, regardless what the ERG's say. Many things can, and already have gone wrong, when a machine or vehicle has not been properly disabled. There are enough cases where vehicles or machines suddenly started to move or work, where arcing and sparking caused fires, or where airbags deployed during extrication efforts.

If the vehicle is also equipped with an alternative power source such as a high-voltage battery, safely disabling the complete system may become even more challenging as some vehicle manufacturers advise rescuers to follow special disabling procedures in their Emergency Response Guides. While some manufacturers advise emergency responders to switch off the ignition and to disconnect the 12-volt battery of the vehicle some vehicles require additional action. One example that demonstrates the differences in shut down procedures is the Buick LaCrosse equipped with "e-Assist". In addition to switching off the ignition, the manufacturer advises emergency responders to cut two marked cables in the engine compartment, in a recommended order, to disable the vehicle (see fig. 6).

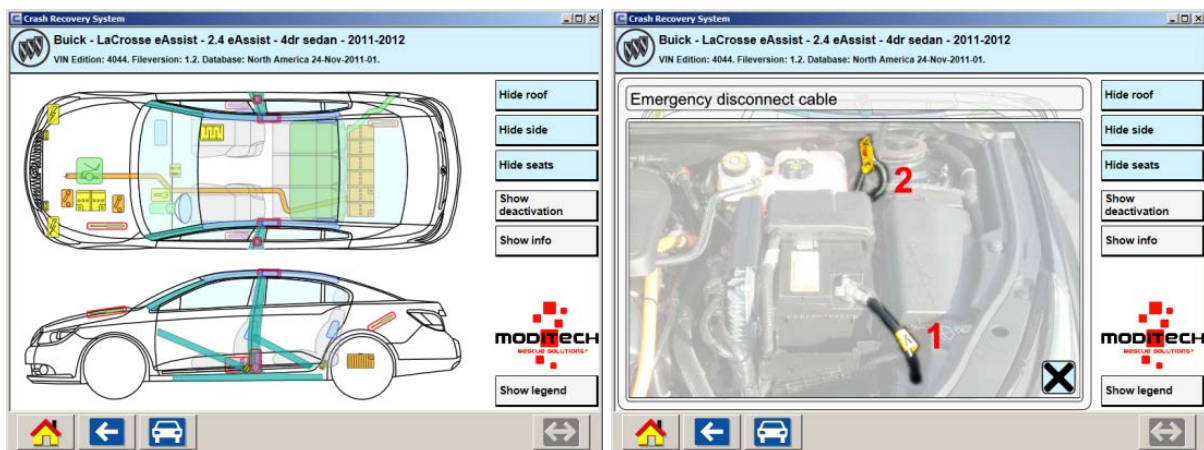


Figure 6: Screenshot of the 2012 Buick LaCrosse 12-volt battery cables. Cables should be cut in the manufacturer's recommended order.

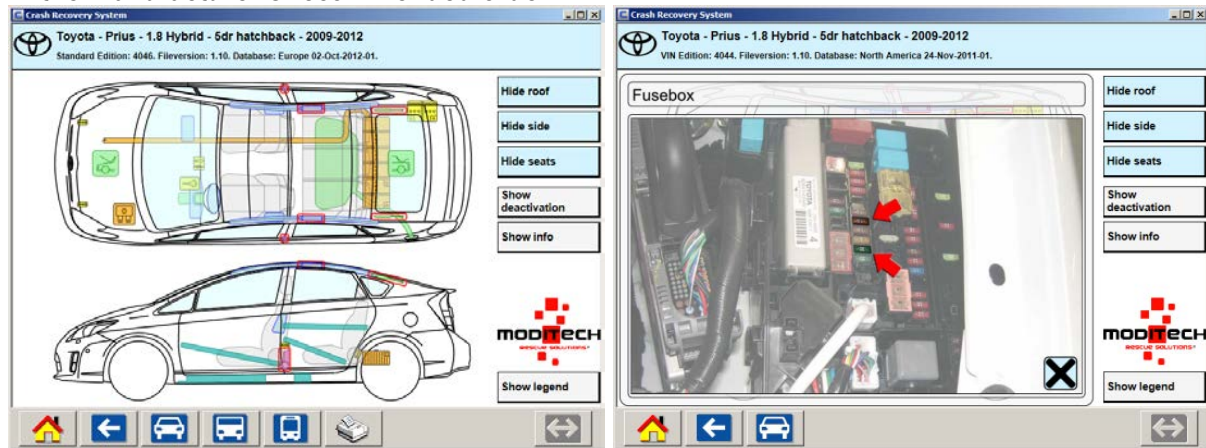


Figure 7: The Toyota Prius ERG advises to pull certain fuses in addition to disconnecting the 12-volt battery.

Most Emergency Response Guides and the Crash Recovery System also provide information for those instances when the ignition cannot be switched off on an electric, hybrid or alternative powered vehicle. As stated before, disconnecting the 12-volt battery only may not be enough to disable those vehicles in such a case. That is why the vehicle manufacturer advises emergency responders to pull certain fuses, cut specially marked cables, remove the service plug, or do similar things in their guidelines.

An example of this is the Toyota Prius (now in its third generation). If the ignition cannot be switched off, the manufacturer-provided ERG advises rescuers to pull certain fuses from the fuse box. This is in addition to disconnecting the 12-volt battery (see fig. 7). Another example is the pure-electric Nissan Leaf. If neither the ignition button nor the engine compartment is accessible the manufacturer advises emergency responders to remove the service disconnect switch (service plug) with appropriate PPE (see fig. 8).

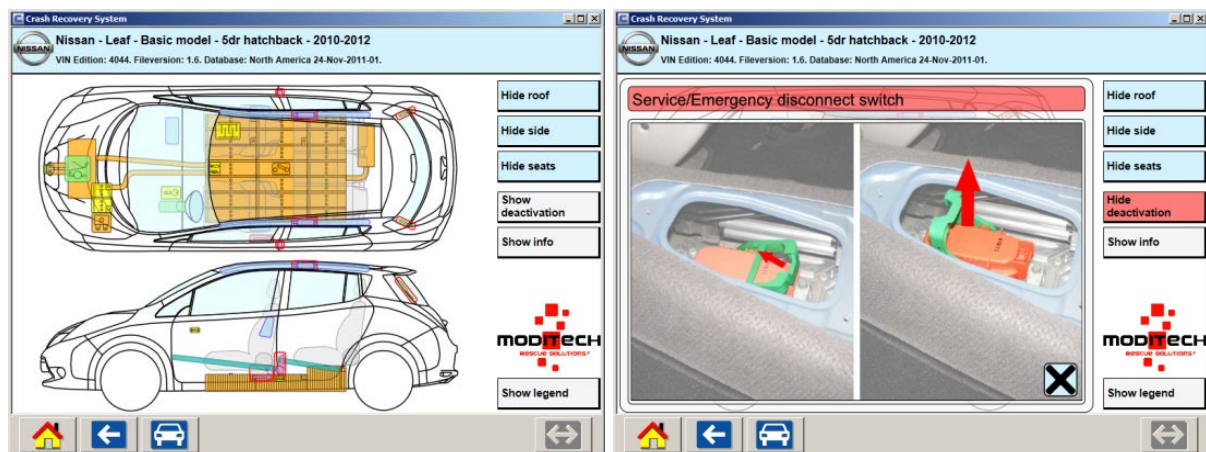


Figure 8: If other shut down procedures cannot be accomplished in the Nissan Leaf, the manufacturer advises to operate the high-voltage disconnect. The access panel to this switch is located in the center of the rear floorboard area and requires some simple hand tools to remove the access panel cover.

Knowing the right measures to disable the vehicle is therefore very important. As it is impossible to remember all the vehicle specific methods, a vehicle information system such as the Crash Recovery System can provide all the necessary info. Other than the Emergency

Response Guides, the CRS carries all information in a standardized format to allow quick orientation and selection of the right disabling procedure.

As the vehicle shut down operations progress, outside rescuers need to make sure to check with the interior rescuers that all electrically powered beneficial systems for the rescue have been used before actually disconnecting the battery or disabling the vehicle with the procedure set by the vehicle manufacturer. Moving electrical seats, lowering windows, opening the rear hatch or the roof window may all be electrically controlled actions that may make rescue measures and extrication easier.

After all of these steps are completed, the vehicle should be able to be safely approached to begin extrication efforts. Remember, throughout the extrication operation rescuers will still need to continuously assess the vehicle for additional hazards or challenges to the rescue operation, such as airbag stored gas inflators, high-strength steels, fuel or energy system components, etc. Another important point to remember is that after all patient extrication activities are completed, the incident commander should make other responders (police investigators, tow truck operators, etc.) aware of the make/model of the vehicle and what depowering and other safety activities were completed by the rescue service. In some cases, vehicle manufacturers require additional de-powering procedures to be performed by dealer technicians or other specially trained service personnel. It is also important to remember that the safety of other responder groups is just as important as the safety of rescuers.

Rescuers need to keep one other important point in mind as they are performing the various shutdown procedures. Vehicle manufacturers are producing so-called “emergency response guides”, especially for electric, hybrid, and other alternative powered vehicles. Each of these ERG’s details the manufacturers recommended procedure for securing the vehicle. The unanswered question is what will the liability be to rescuers for failing to follow these procedures, especially if something happens and/or someone is hurt? If rescue companies have tools available to know the proper procedures, follow the manufacturer’s guidelines, and still stay trained in and follow the proper procedures, that question will never have to be answered. In closing, keep in mind that throughout the article, several different vehicles have been used to highlight examples of many of these steps and the differences that will be encountered in the response to motor vehicle collisions. There are hundreds of makes/models of vehicles on the road today throughout the world, and no one rescuer, or even rescue company, can be knowledgeable on every single vehicle that may be encountered. Again, this it is why it is imperative to use a systematic approach at all motor vehicle collisions, as well as using the most appropriate resources to determine what is inside.