Optimizing Vehicle Suspension for Overlanding

First time teaching this, please help me refine it. Please reserve specific questions for the end. Questions for clarification, yes please.

Introduction: The focus of this course is to give students the tools to make the right decisions about suspension modifications, and to diagnose suspension problems related to overland vehicles. It must be understood that the requirements of an overlanding vehicle are not the same as an offroad race vehicle, street racer, or other subclasses of vehicles. Just because you see something used on a race vehicle does not mean it belongs on your overland vehicle. Our vehicles most often carry heavy loads, or varying loads over all kinds of terrain, while still providing good pavement manners. That is actually a much harder task than designing a specific suspension for a dedicated race vehicle. Knowledge is power!

1. Suspension Related Terms
    a. Spring rate: Spring rate is the resistance of the spring per distance of compression or deflection. On coil springs this is expressed in pounds per inch. Springs can either be linear in rate or progressive.
    b. Damping: Is the effect of the shocks, generally speaking, but damping can also be applied from bump stops and other components
    c. Oversteer: The tendency of the vehicle to turn more sharply than indicated by the direction of the tire. When traction is low, this will cause the rear of the vehicle to thrust to the outside of the curve. This is the classic “spinout” scenario.
    d. Understeer: The opposite of oversteer. The vehicle tends to “plow” straight ahead when the tires are turned. The front of the vehicle will drift to the outside of the curve while the rear holds to the inside.
    e. Weight transfer: Any time a vehicle enters a dynamic shift, whether that be from braking, accelerating, or cornering, the vehicle undergoes weight transfer. It simply means that weight transfers from some tires to other tires.
    f. Sway control: is designed to control side to side weight transfer
    g. Load control: designed to hold and control the weight of the vehicle.
2. Suspension Components
    a. Springs, coil and leaf: Springs in the suspension system are designed to support the weight of the vehicle and provide the suspension travel needed to effect a smooth ride. Coil springs are superior for providing predictable compression performance on vehicles with a set weight. This is because the progression of the spring rate, although lower, can be very finely tuned. They can also provide more travel than leaves. For this reason, coil springs are used extensively on race vehicles. Leaf springs are far more crude and ancient. The earliest examples were designed in France for use on carriages during the 17t century. Leaf springs remain a very important design feature

of modern vehicles designed to carry loads. This is because a much more progressive rate can be designed into them. Note collapse leading to roll over. Special Note: The affect of shackle angle and length on spring performance.

b. Shock absorbers: Have only one job: to control the movement of the spring
c. Bump stops: Cushion and stop the upward travel of the axle during extreme compression of the spring.
d. Limiting strap: Cushion and stop the downward travel of the axle during extreme extension of the spring.
e. Sway bars: Control side to side weight transfer
f. Load control devices, airbags and microcellular polymer springs: Airbags primarily add weight control. Microcellular springs assist the steel springs, but have the unique property of rebounding at a slower rate than they compress. In this way they add an element of damping along with weight control.

3. Suspension Component Interplay (Vehicle Dynamics)
   a. The function of springs: Springs must maintain the intended ride height under load, provide for adequate suspension travel, and be designed to work through their full range over the intended terrain.
   b. The function of shocks: Modern shocks have become extremely high tech because the job they perform is extremely demanding. They must provide spring control at low axle speeds as well as high axles speeds while effectively dissipating the heat generated by this activity. The best shocks have some degree adjustment to allow the driver to tune the vehicle for the road conditions and intended use. The adjustments most often seen are some combination of low speed compression damping, high speed compression damping, and rebound damping. One important role of shocks is to control the speed of weight transfer. Note that it cannot alter the amount of transfer! Getting this adjustment right can dramatically improve the controllability and comfort of the vehicle both on and offroad
   c. Why we have bump stops: to prevent catastrophic impact of suspension components during hard compression. Bump stops may also be used to prevent recurving of leaf springs or coil bind on coil springs.
   d. Why we (may) have limit straps: I say “may” because most often these are not needed on overland vehicles. A slow and controlled extension of the suspension is more generally the rule, and this rarely results in suspension damage. You see this damage more often in race vehicles that get airborne and/or have very flexible suspension systems operated at high speeds.
   e. How Sway bars effect handling: Perhaps the most misunderstood component. By controlling the weight transfer side to side during cornering, sway bars reduce the unloading of the inside tires. This keeps the weight more equally distributed on the four tires, which maintains traction. It also adds a measure of predictability which feels better to most drivers. Swaybars have another more subtle function, and that is to tune understeer and oversteer. Front bars induce understeer and rear bars induce

oversteer, BUT in an overland type vehicle where the rear CG tends to be higher than the front, the oversteer effect of a rear bar is largely offset by the reduction of weight transfer. In many overland vehicles, the addition of a rear swaybar has a positive effect by countering some of the factory induced understeer designed into most modern production vehicles. One last downside to using a heavy front swaybar, is that it limits articulation. While a swaybar may reduce the probability of a rollover on the street, it could encourage a rollover offroad.

f. When do I need load control devices? These are most useful when the loads carried vary a good bit. This could be due to hitch weight or cargo weight.

4. Putting It All Together
   a. Analyzing your suspension: using the understanding gained above, try and pinpoint what the suspension is actually doing. Accurately diagnosing problems is the only way to solve them. Ride? Trail manners? Road manners? Handling? Kofa case study, lessons from racing,
   b. Having clearly defined goals
   c. First, do no harm: Make sure you clearly understand the consequences of the changes you intend to make. Altering any factory system can dramatically effect the performance and safety for better or for worse
   d. The fallacy of lifting IFS: compression vs rebound, a zero sum game.
   e. Moving slowly towards perfection: make small changes when possible to assess whether you are moving in the right direction
   f. Fine tuning: be patient and make the last adjustments over time
5. The Two Components that are most overlooked!
   a. The role of tires: tire weight, sidewall strength, and air pressure are all factors that effect suspension and steering performance.
   b. The role of the chassis: 2 types of frame flex. Let it flex in twist! Avoid or correct beaming
6. Safety Considerations
   a. Raising your vehicle: Minimize lift, simple as that.
   b. Component compatibility. Common issues are: inappropriate shock length, improper bumpstops, shocks with inadequate damping rates
   c. Unqualified modifications: Some modifications, especially to frames, can lead to catastrophic failures. These should only be attempted by qualified fabricators with engineering knowledge. Inappropriate gusseting and bracing is another common issue.
   d. Proper Loading: First off, try to minimize weight. Excess weight is the bane of overlanding. Try to avoid heavily loaded rear bumpers, or any weight behind the rear axle. Also avoid weight on roof racks. Save these areas for objects that are light but bulky. Minimize polar moment of inertia.
   e. Understanding limitations: overlanding vehicles are the great compromise. Choose your focus

7. Open Discussion, Audience Q&A