2021 AMERICAN SOLAR CHALLENGE

MOV ENERGY METERING & SCRUTINEERING

IEF Solar Car Conference
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Presented By IEF MOV Inspectors

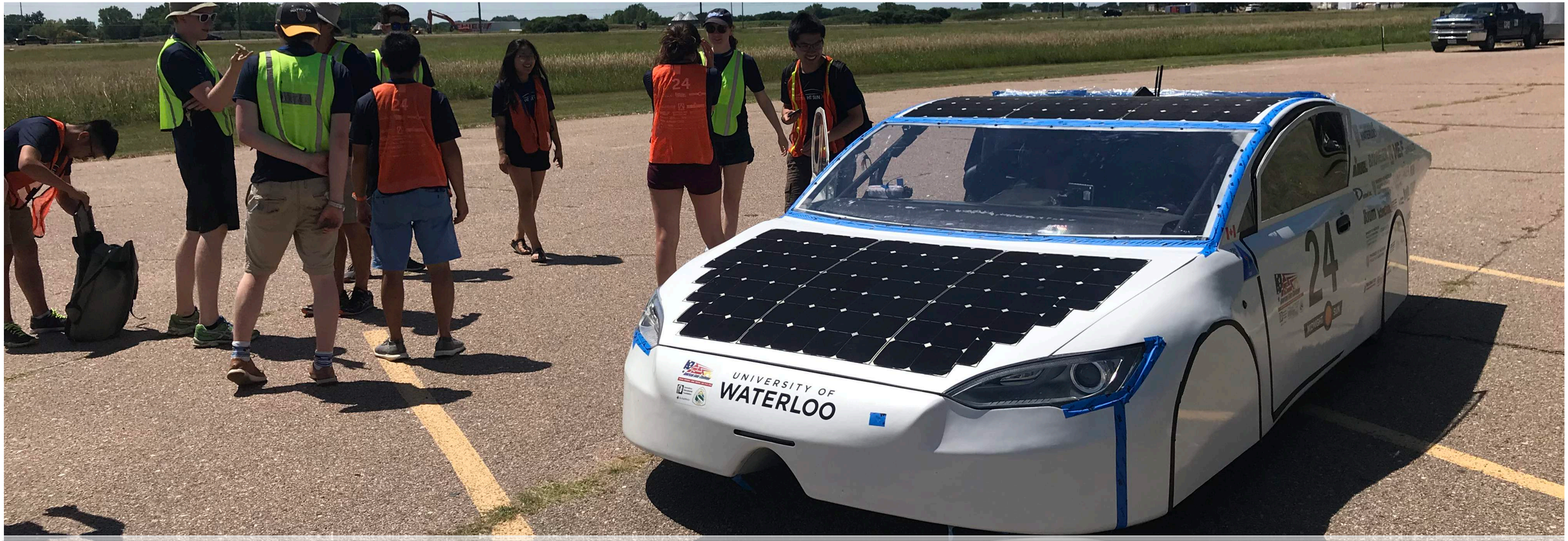
Evan Stumpges <evan_stumpges@americansolarchallenge.org>
Dale Reid <dale_reid@americansolarchallenge.org>

MOV AGENDA TOPICS

- Scoring
- Energy Metering
- Impound
- Scrutineering
- Questions & Answers

THIS CONTENT IS INTENDED TO SUPPLEMENT THE REGULATIONS BUT DOES NOT SUPERSEDE THEM

DISCLAIMER



MOV SCORING

MOV SCORING - ASC 2021 REGULATION SECTION 13

- The goal for Multi-Occupant vehicles is to efficiently transport people along a predefined route with considerations for practicality while driving at or above the Target Average Speed for the event.
- Multi-Occupant vehicle teams are ranked by **S** value (highest score is best)
  - **S = (D / E) x C x T x P**
    - **D** is the Total Person-Mile Distance - higher values are better
    - **E** is the Total External Energy Usage - lower values are better
    - **C** is the Completion Factor - higher values are better
    - **T** is the Target Speed Derate - higher values are better
    - **P** is the Practicality Score - higher values are better
  - This scoring formula presents a challenging multivariable optimization problem. Make a strategy!
  - Having a reliable vehicle is especially critical to being successful in this class!
- Multi-Occupant vehicles shall remain in the same Scrutineered configuration throughout the duration of the Event. All practicality features shall remain intact throughout the duration of the Event.

MOV SCORING - ASC 2021 REGULATION SECTION 13

- Person-Mile Distance (**D**)
- ASC Segments - Between Checkpoints/Stage Stops + Loops
  - Each Segment of the Event will yield a Person-Mile Distance calculated as
    - (Tour Distance driven in Miles) x (Min occupied solar car seats)
  - Similar to the SOV class, MOV teams can drive loops to increase distance
- FSGP Laps
  - Each valid completed Lap will yield a Person-Mile Distance calculated as
    - (Lap Distance driven in Miles) x (Min occupied solar car seats)
- The summation of these Segment/Lap Person-Mile Distances will yield a Total Person-Mile Distance for the team.

MOV SCORING - ASC 2021 REGULATION SECTION 13

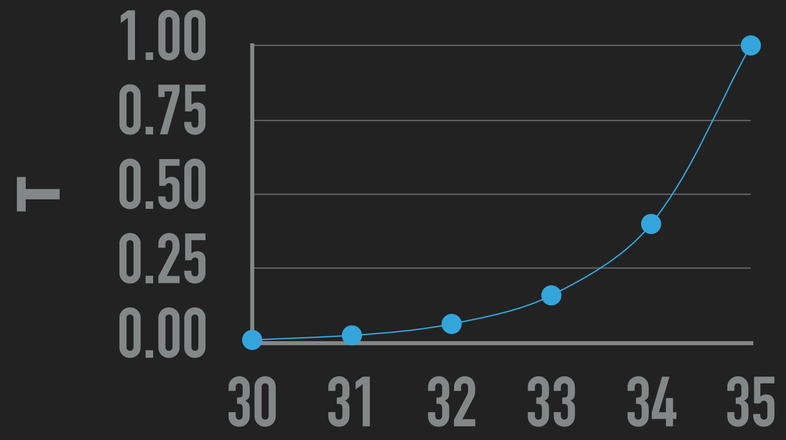
- External Energy Usage (**E**)
  - Calculated as
    - **(n+1) x Q + M**
      - **n** is the number of times the battery is charged from unmetered external energy
      - **Q** is the energy capacity of the battery in kWh calculated at Electrical Scrutineering
      - **M** is the total metered external energy in kWh used to charge the battery
- Metered vs. Unmetered External Energy
  - Metering enables the flexibility of partial battery charges to optimize race strategy
  - Metered charging incentives MOV teams to still perform morning/evening solar charging
  - Metered charging is impacted by the conversion efficiency of the onboard vehicle charger
    - A more efficient charging system will help your score!
  - Unmetered charging is available to teams who are unable to implement J1772/onboard charging
  - If for any reason an external charge isn't properly metered and recorded, it will count as unmetered.

MOV SCORING - ASC 2021 REGULATION SECTION 13

- Completion Factor (**C**)
  - Calculated as
    - (Driving Distance – Penalties) / (Highest Driving Distance of Any MOV)
- Your score is impacted by the performance of the furthest driving MOV team

MOV SCORING - ASC 2021 REGULATION SECTION 13

- Target Speed Derate (**T**)
- **V** is the Target Average Speed which is equal to
  - 35 MPH for ASC
  - 30 MPH for FSGP (subject to change based on track selection)
- **Va** is the team's Overall Average Speed which is calculated as
  - ASC: Total Tour Distance driven divided by the total elapsed Tour Time, in MPH
  - FSGP: Average speed of all valid laps completed during the event, in MPH
- If **Va ≥ V** then the target speed has been met and the Target Speed Derate is
  - **T=1**
- If **Va < V** then the target speed has not been met and the Target Speed Derate is
  - **T=0.4^(V-Va)**
- <u>There is a high incentive for teams to average above the Target Average Speed!</u>



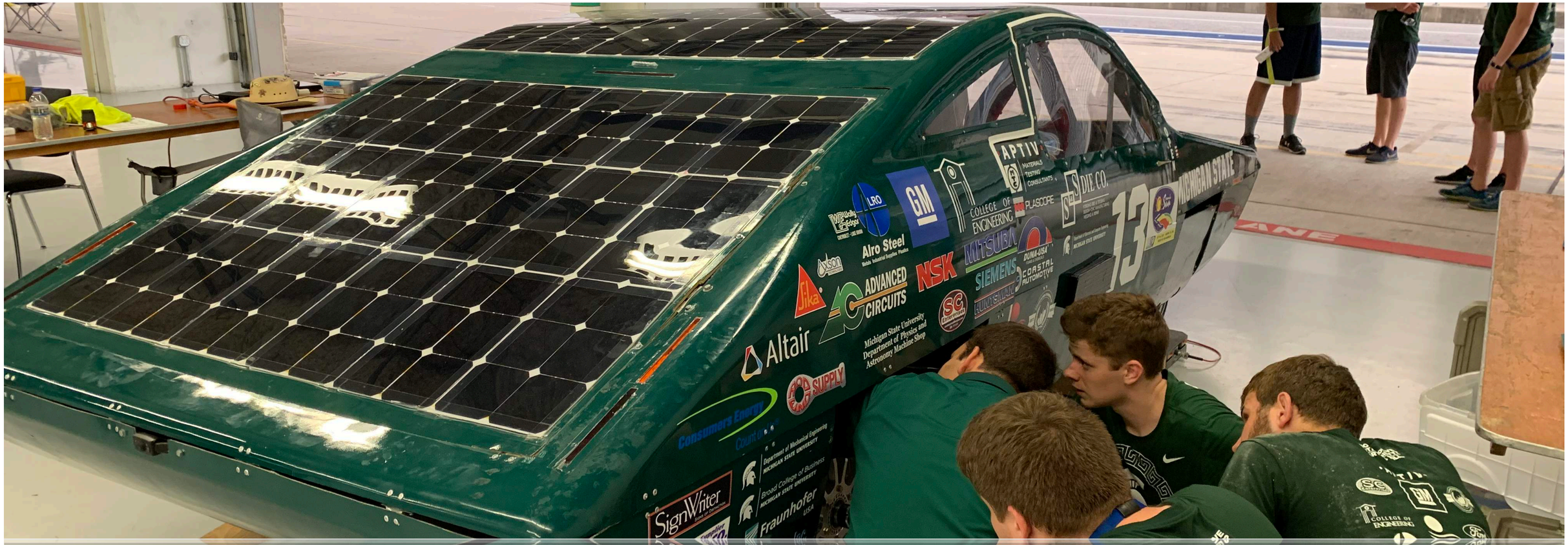
MOV SCORING - ASC 2021 REGULATION SECTION 13

- Practicality Score (**P**)
  - The practicality scoring factor is only for ASC events and is removed from the FSGP scoring formula.
- The Practicality Score for a Multi-Occupant vehicle team will be determined by a panel of judges appointed by the ASC Organizers. It will be based on a mix of subjective and objective evaluations.
- Teams will be required to prepare a “window sticker” for their solar car which describes the attributes of the car for publication through social media on the morning of judging.
- Practicality judging will be conducted on the solar cars during the rest day prior to the start of the Tour. The score from each judge will be averaged into the overall Practicality Score for the solar car ranging from 0-1.
  - The MOV Practicality Judging Rubric will not be released to judges or teams until the morning of the judging.
- Prior to the start of ASC, Officials will review and compile the Practicality Scores for all MOV teams and each team will be provided with their own score along with a copy of each judge’s MOV Practicality Judging Rubric evaluation of their vehicle.
  - In order to maintain an element of surprise, practicality Scores of all teams will be made public at the ASC Awards Ceremony at the conclusion of the Event.

MOV SCORING - ASC 2021 REGULATION SECTION 13

- The following is an example list of areas that may be considered for practicality scoring
  - Driver and Occupant Amenities
  - Quality of Features
  - Infotainment System
  - Phone Connectivity
  - Ease of Operation
  - Internal and External Styling Fit & Finish
  - Watertight Cabin
  - Visibility
  - Seats
  - Doors
  - Cargo Space
  - Spare Tire Kit

- This list is not intended to be comprehensive, additional items may be considered, and not all items may be included in the final scoring



MOV ENERGY METERING

MOV METERED CHARGING

- Why metered charging?
  - MOVs aren't regulated on battery weight
    - This allows teams the flexibility they need to appropriately size the battery to support their vehicle's number of occupants and practicality features
  - Assessing MOV teams as though they fully charged their battery from empty any time they plug in is not accurate or fair
    - Previous ASC/WSC regs severely penalized topping off the battery pack with partial charges
    - Previous ASC/WSC regs encouraged starting the last competition day with a full pack even if not needed to finish the event
    - Enabling metered charging allows teams to benefit from partial charges to gain more control over their scoring formula
- Why is it taking so long to implement?
  - <u>It has taken time to reach agreement on the following</u>
    - Developing a solution to accurately monitor charging energy at different voltage/current levels across all MOV teams
    - Standardizing teams on the J1772 EV charging protocol and defining minimum safety requirements for metered charging
    - Determining where in the charging circuit the monitoring would be placed
    - Ensuring that teams won't be able to bypass the charge meters during the event

MOV METERED CHARGING

- What are the vehicle requirements to take advantage of metered charging?
- Securely mounted J1772 vehicle power inlet receptacle and compliance with the SAE J1772 EV charging protocol
  - Note: vehicles designed to use a different standard EV connector may use an adaptor cable provided it is carried in the vehicle and doesn't exceed 1m in length
  - Team must provide their own Level 1/Level 2 J1772 Electrical Vehicle Supply Equipment (EVSE) in order to connect their vehicle to an energy source for charging during the event
    - EVSE does not need to be carried inside the solar car
    - Event organizers are not responsible for providing external energy sources or adapters for teams to use
    - It is recommended for teams to carry a variety of adapters to use their EVSE with common electrical outlets as well as a solution for charging from their generator if necessary
    - Teams are allowed to use commercially available J1772 charging stations if they can find an open one during the event
- Rigidly mounted onboard charger that accepts external energy from a 120-240Vac power source and outputs DC power with an adjustable current limit to charge the battery
  - The vehicle power inlet ground connection must connect to the charger's AC input ground and be tied to the charger chassis if it contains any exposed metal.
  - The charger's AC input and DC output must be electrically isolated from each other as well as from the vehicle chassis

MOV METERED CHARGING

- What are the vehicle requirements to take advantage of metered charging? *(Continued)*
- Accommodations for an onboard AC energy meter provided by the Event Organizers that will connect inline between the vehicle power inlet and the onboard charger's AC input
  - Meter connections will be NEMA 14-50
- Dedicated power port and charger relay for the battery box that is utilized only for external energy charging.
  - All exposed connectors/conductors on the AC/DC charging power lines between this battery box port and the J1772 vehicle power inlet must be enclosed in an approved manner that can be locked/sealed by the Event Organizers to prevent any of these connections from being unplugged or tapped into to bypass the energy meter or the J1772 power inlet.
  - The team must also provide a way to seal their charger such that unauthorized access to its internal components is prevented.
- Charging Safety Features
  - Any covers for AC or DC power connections must be nonconductive, marked with "Caution: High Voltage", and only removable with the use of tools
  - All conductors used for MOV charging must be appropriately sized to carry the vehicle's maximum possible charge current.
  - When a J1772 plug is connected, the vehicle must automatically prevent the use of the drive motors.
  - When charging from an external energy source the BPS must always actively monitor the battery state and the MOV charger must be isolated during a BPS fault

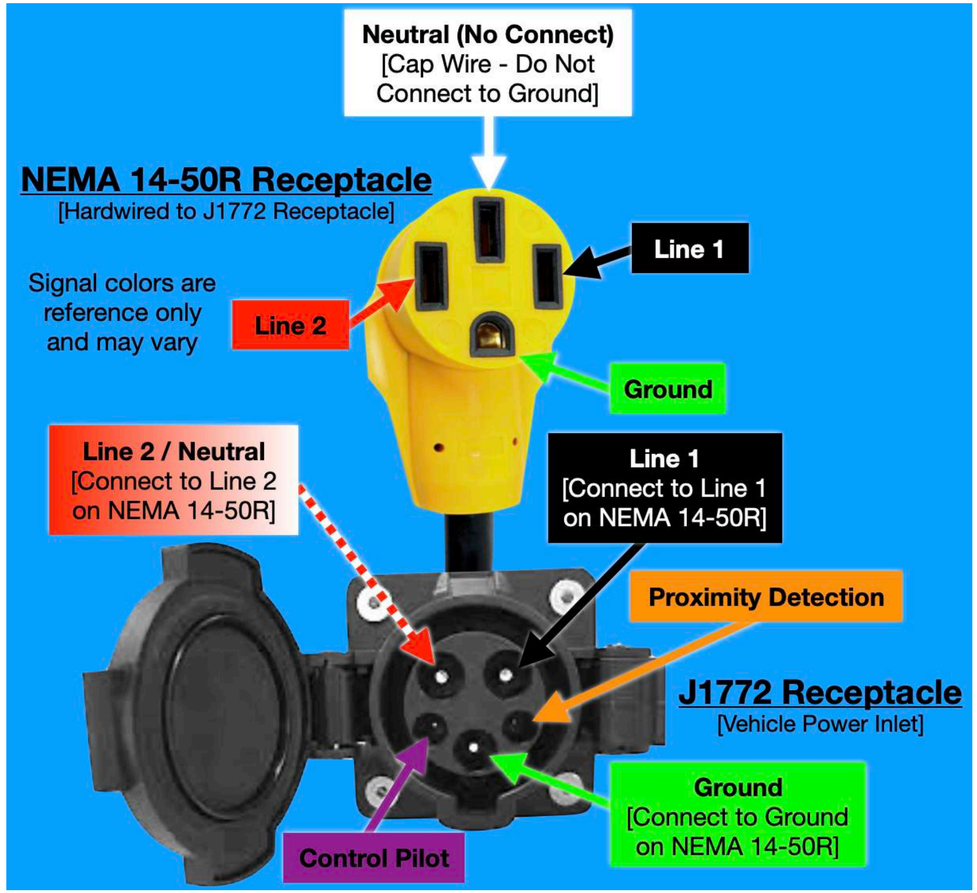
MOV METERED CHARGING

- IEF Meter Mounting
  - Teams are not allowed to drill holes into the energy meter enclosure
  - 3M Dual-Lock or similar is acceptable to use on the bottom of the enclosure
  - Straps are acceptable to use around the enclosure
  - Open to other ideas for mounting
- The display of the meter needs to be visible to be read each day

IEF Energy Meter Info

- This onboard energy meter will be provided to MOV teams by IEF
- The meter must be installed in the solar car during Scrutineering
- EKM Omnimeter Pulse v.4 meter provides revenue grade accuracy
- Flexible 120-240 Vac input voltage at up to 40A current
- Watertight enclosure with sealed cable glands
- ~$500 estimated cost for this charge meter solution

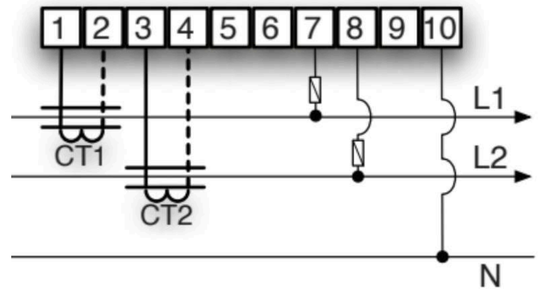
J1772 to NEMA 14-50 Wiring

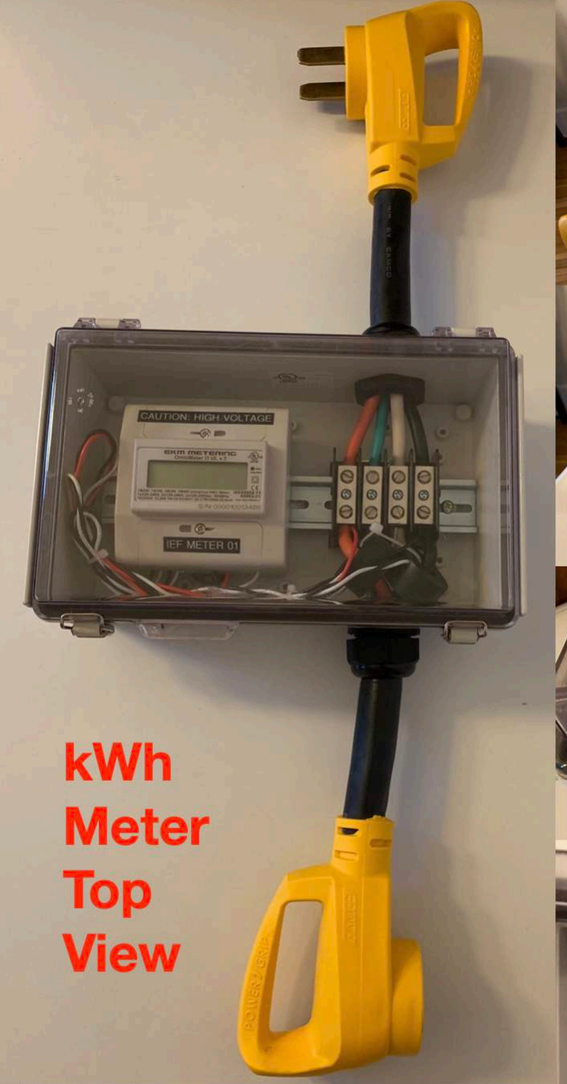


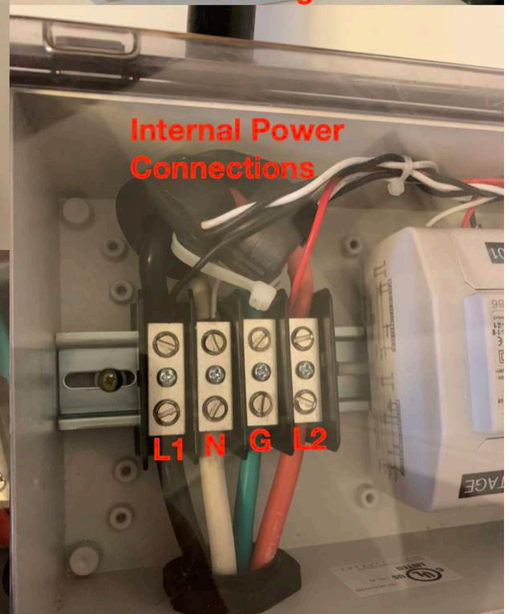
Meter BOM Reference

Item	QTY	Unit Cost	Total Cost
EKM Omnimeter Pulse v.4 – Universal Smart Meter	1	$ 260.00	$ 260.00
EKM Split-core CT, 200A Current Transformer	2	$ 45.00	$ 90.00
EKM Watertight Enclosure with Hinged and Latching Lid (6.7” x 10.63” x 4.33")	1	$ 80.00	$ 80.00
Camco 55215 18" PowerGrip Extender - 50 AMP	2	$ 19.95	$ 39.90
Marathon Special Products 1414300 Splicer Block, 4-P, 115A, Line: 2AWG-14AWG	1	$ 18.08	$ 18.08
Waterproof Cable Gland (2pc Set)	1	$ 10.05	$ 10.05
Total			**$ 498.03**

IEF Meter Box Current & Voltage Sensor Reference







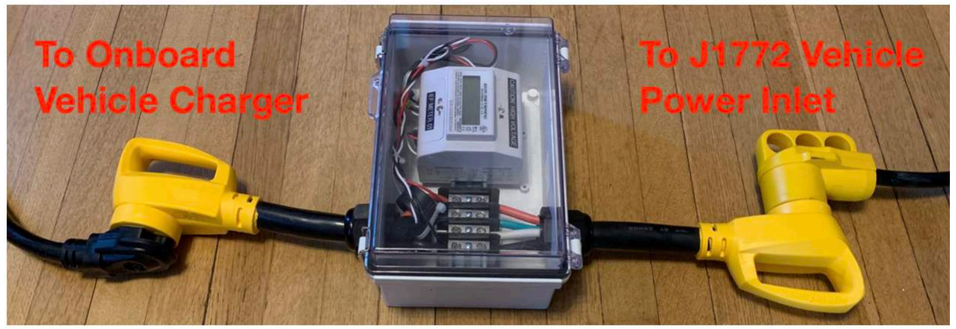
Meter Display Cycle

- Total kWh Energy
- L1 Volts
- L2 Volts
- L1 Amps
- L2 Amps

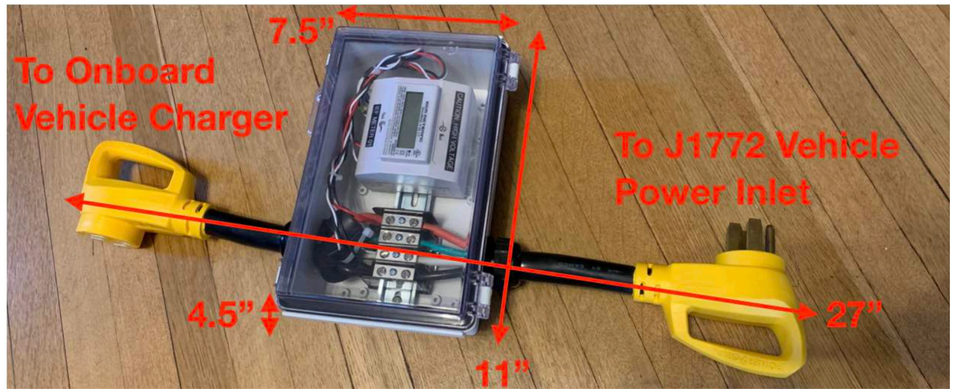
How to Integrate kWh Meter Onboard Solar Car

MOV solar cars must feature an inline NEMA 14-50 connection between the J1772 Vehicle Power Inlet and the Onboard Vehicle Charger. When not at an ASC/FSGP event, the NEMA 14-50 connectors will be directly connected as shown below.

When the team comes to an ASC/FSGP event, they will disconnect the NEMA 14-50 connectors and plug them into the kWh Charge Meter as shown below. The NEMA connectors will be sealed together for the duration of the event so the meter can't be bypassed.



The kWh hour meter is watertight, weighs 6lb, and has enclosure dimensions of 11" L x 7.5" W x 4.5" H with a connector to connector length of 27".



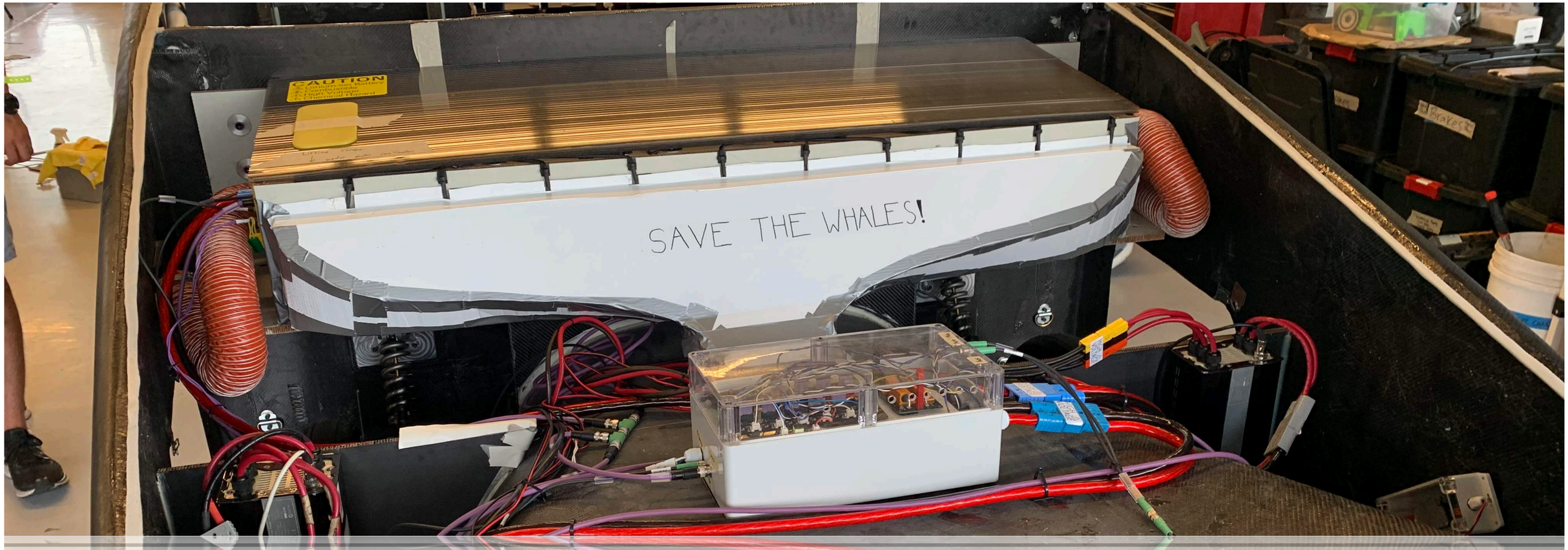
MOV IMPOUND

IMPOUND

- Multi-Occupant vehicles are exempt from the requirement to remove the batteries from the vehicle for impound purposes
- They must provide alternative and reliable means of securing the batteries to prevent any unmetered charging of the batteries during impound hours
  - MOV impound state must lock access to the battery box lid and any power connectors to the motor, solar array, etc.
    - MOV battery enclosures must not contain any externally accessible hinge/latch hardware
  - In impound configuration the metered J1772 power inlet must be the only functional/accessible battery power connection
- Failure to properly impound during the designated hours at the Event will result in a full unmetered external energy charge being added in the team’s Score.

IMPOUND

- When is it OK for an MOV team not to impound?
  - Any time an MOV team fails to properly impound during the designated hours they will be assessed a full unmetered external energy charge in their Score
  - Any time an MOV team elects to charge from unmetered external energy they must first officially declare this intention to event organizers (or observer during the Tour)
    - MOV teams that have indicated they will be charging from unmetered external energy overnight do not need to impound that night
- Why might a team choose to conduct unmetered charging?
  - Failure to gain certification for metered charging during Scrutineering
    - Vehicle is missing or has nonfunctional onboard charger, J1772 receptacle, EVSE, etc.
    - Vehicle design is unable to accommodate the onboard IEF energy meter
    - Vehicle doesn’t satisfy metered charging impound/safety/lockout requirements
  - Battery pack is drained and team decides it is more beneficial to accept the full unmetered external energy charge and bypass the efficiency losses of their onboard charger



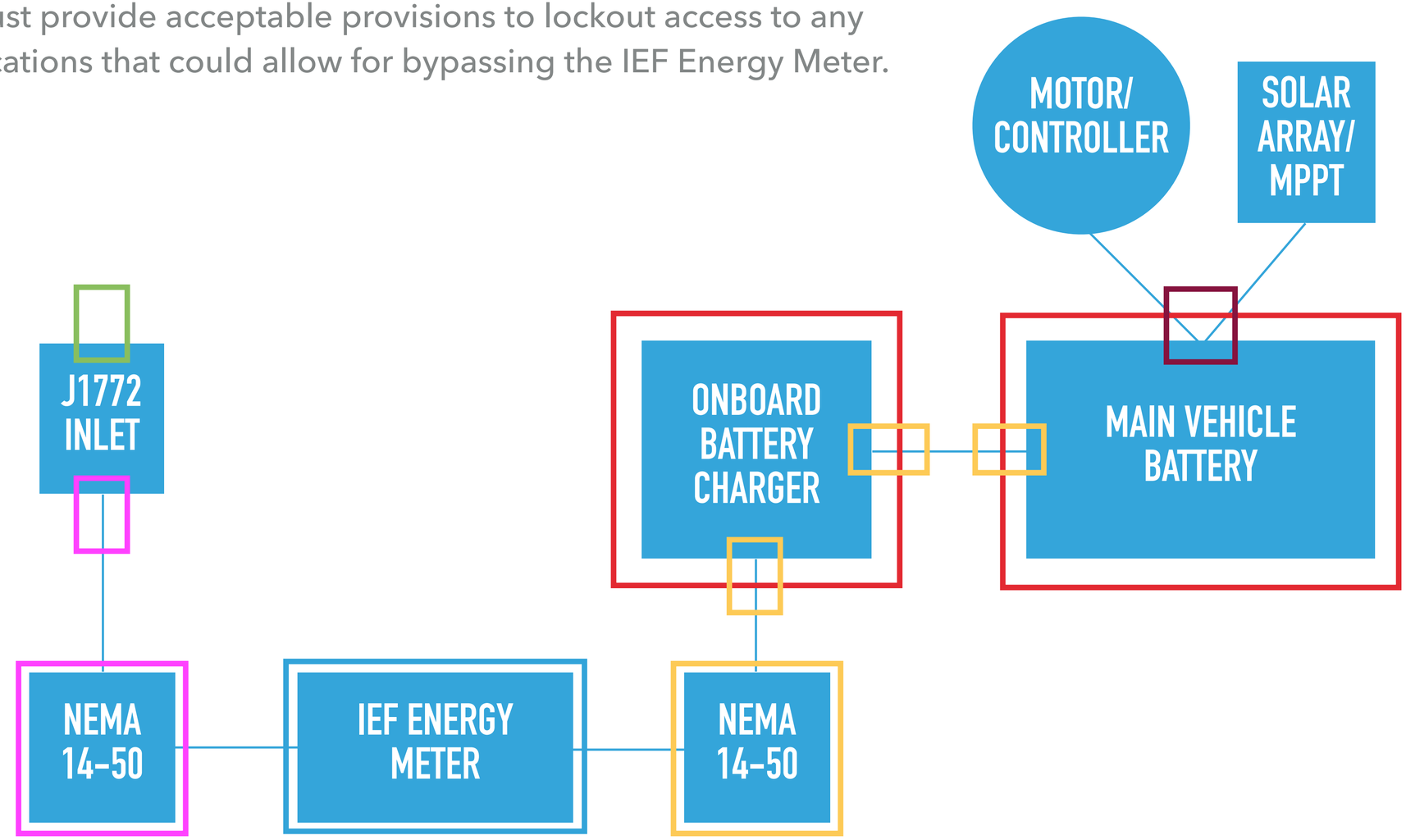
MOV SCRUTINEERING

REVIEW AND ANSWER QUESTIONS ON

DRAFT SCRUTINEERING SHEETS

METERED CHARGING LOCKOUT LOCATIONS TO BE INSPECTED

In order to be certified for metered charging, MOV teams must provide acceptable provisions to lockout access to any locations that could allow for bypassing the IEF Energy Meter.



Color Key

- Provision to lockout internal access
- Provision to lockout connector access
- Provision to disconnect and lockout access during impound
- Meter enclosure is provided locked out
- Exposed conductors not allowed and must prevent inadvertent disconnection but lockout not required
- J1772 is always accessible to teams certified for metered charging

QUESTIONS & ANSWERS

QUESTIONS & ANSWERS

- Are any teams not planning on using metered charging?
  - How many teams have EVSE charging equipment?
  - How many teams have successfully implemented and tested J1772 to charge their battery?
  - Have any teams tested J1772 charging from a generator?
- Would any MOV teams be interested in advance access to an IEF energy meter to integrate and test in their vehicle?
  - Would likely require a $500 deposit refundable upon return of the meter
- What questions/concerns do MOV teams have?