Uncovering Hidden Data in CCS Charging Sessions: Key to Improving Interoperability

An Educational Webinar
October 2024

QualityLogic

Today's Presenters

- **James Mater, Director of Strategy, Smart Energy, QualityLogic**

  James is one of the industry-leading experts on smart grid standards, interoperability, and the maturity of eco-systems of products based on these standards. He is a member of IEEE 2030.5 WG, IEEE 1547 WG, UL 1741 SC, SunSpec J3072 Profile, OpenADR Profile WG, CharIN NACI WGs and Focus Groups, Chair of the V2G Forum and more.

- **Christian Burns, Software Engineer, QualityLogic**

  Christian is a talented Java, Kotlin, and Python developer and leads the development of the QualityLogic CCS Analyzer.

- **Andrew Dillon, Innovation Technology Leader**

  Andrew is advising QualityLogic in the EV domain. He brings a deep background in the workings of the industry to QualityLogic.

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About This Workshop

- **QualityLogic has been working on technology interoperability since 1986**

- **And on CCS Charging Interoperability since 2021, spending hundreds of hours observing and talking with CCS experts**

- **This is an educational webinar to share what we have learned with the CCS community**

- **It is also a preview of a potential longer workshop aimed at training new CCS engineers in how to analyze charging session files – and how to improve the process**

- **We'd appreciate feedback on the concept of a training workshop on this topic!!**

- **Send comments and questions to jmater@qualitylogic.com**

QualityLogic's Role

- **Focused on Electric Utility DER interoperability standards (loads, solar, storage, EVs and VGI)**

- **Leader in Electric Utility DER Integration testing tools and technical training to enable scaling of DER Integration (including V2G)**

- **QualityLogic contributes to SAE J3072, CharIN CCS, IEEE 2030.5/CSIP, IEEE 1547, UL 1741 and other standards**

- **Core Member of CharIN**

- **Founding member of V2G Forum (www.v2gforum.com) to help harmonize V2G standards**

- **More information at [CCS Interoperability Tools & Services - QualityLogic](#)**

Some of Our Smart Grid Customers

Utilities

SMUD — Sacramento Municipal Utility District — The Power To Do More.

PPL — PPL Electric Utilities

Energy Queensland

PG&E

Énergie NB Power

HORIZON POWER

Hilo by Hydro-Québec

Xcel Energy

aps

SDG&E

KEPCO — Korea Electric Power Corporation

SOUTHERN CALIFORNIA EDISON — An EDISON INTERNATIONAL Company

Hawaiian Electric

nationalgrid

conEdison

AEP AMERICAN ELECTRIC POWER

Hydro Québec

EV Related

HONDA

BMW

Mercedes-Benz

RIVIAN

LUCID

STELLANTIS

ABB

Fermata Energy

NUVVE

dcbel

Tesla

HYUNDAI

heliox — A Siemens Business

LION ENERGY

DEKRA

Inverters

DOOSAN

solaredge

LG — Life's Good

SIEMENS

sunrun

Schneider Electric

SMA

SUNPOWER®

Fronius

GENERAC

ENPHASE

Today's Agenda

- **The EV-EVSE charging interoperability ecosystem**
- **Why interoperability problems exist**
- **The CCS model for achieving interoperability**
- **The CCS standard and interoperability challenges**
- **Process and tools for analyzing charging sessions today**
- **The analysis gap – what are we missing**
- **Solving the analysis gap by automating it**
- **Future trends for CCS charging interoperability testing and analysis**
- **Questions**

EV – EVSE Interoperability Ecosystem

High Level Perspective On Focus of This Webinar

Data Communication & Interoperability

Data communication and interoperability between EV and EVSE is complex, standards-heavy, and evolving

EV IoT Data Ecosystem

- Onboard Battery Charge Manager
- Firmware Versions
- Comms Interface to:
  - EVSE
  - Consumer
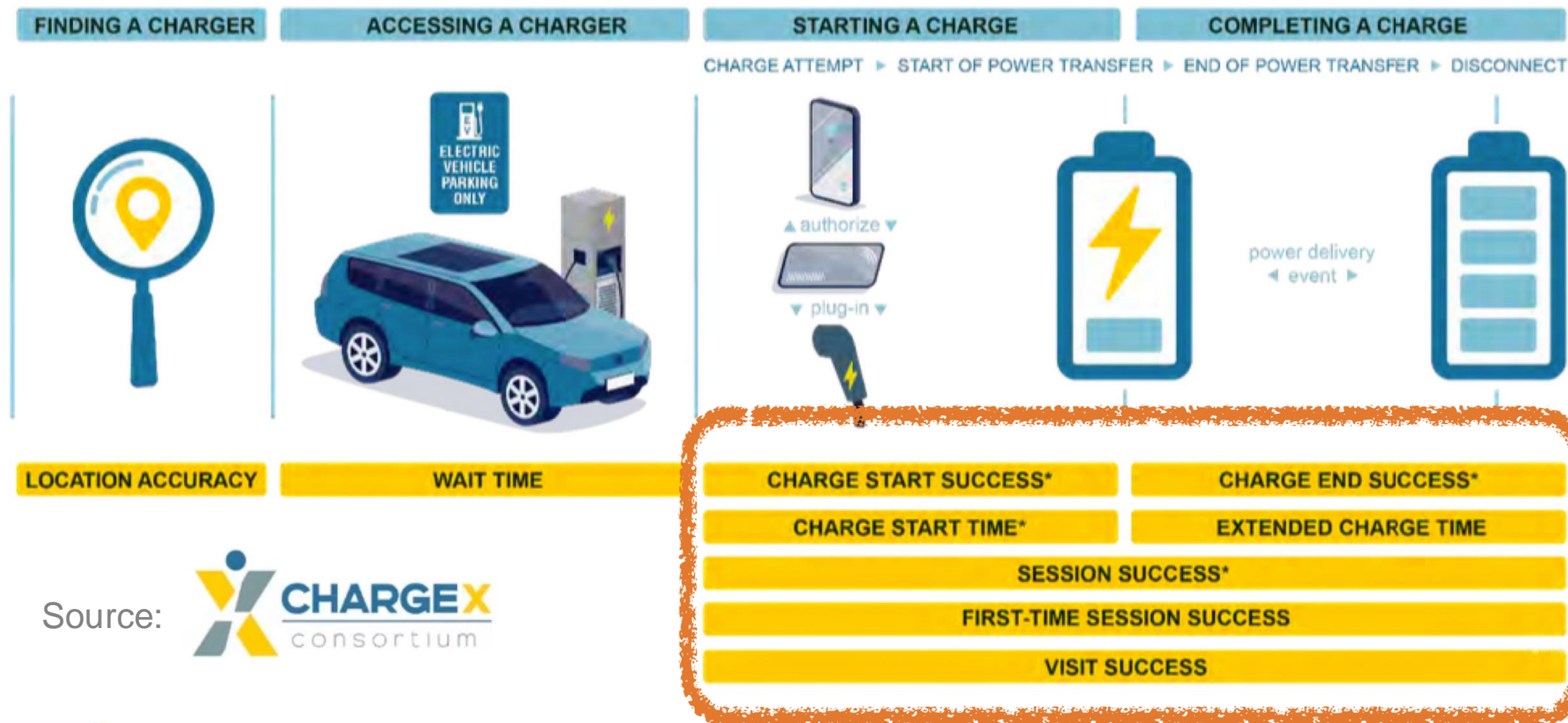 - EV OEM Network

Messaging Between EV and EVSE

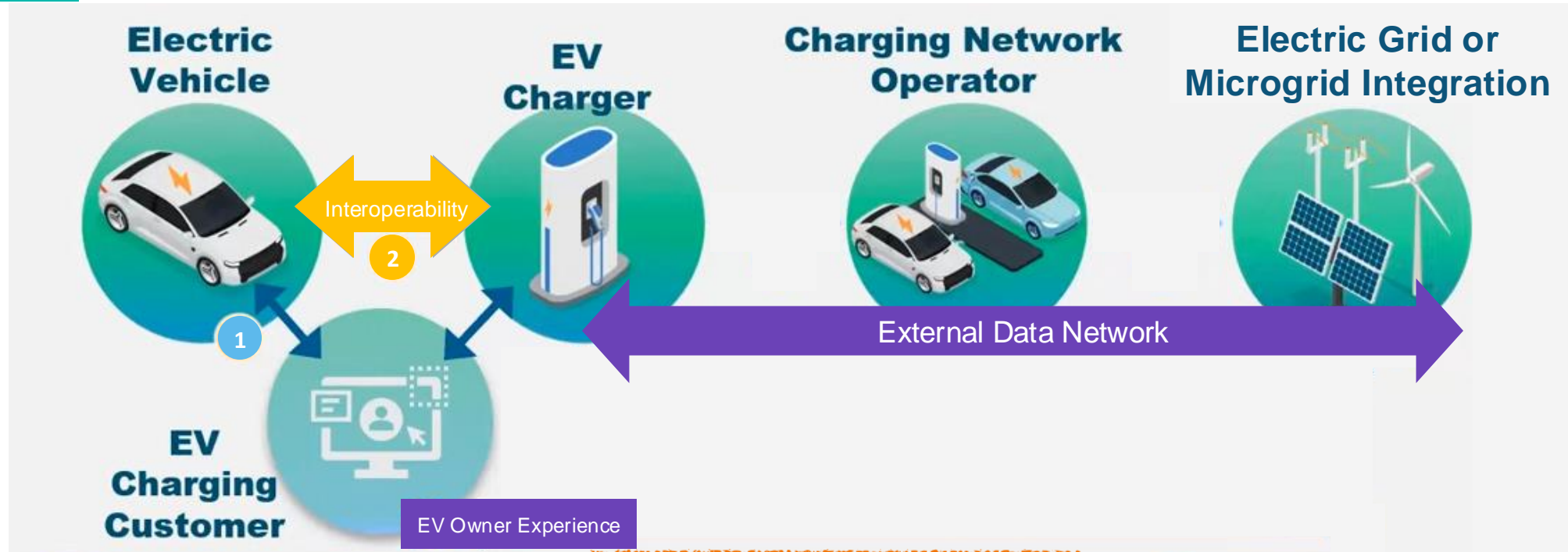**EVSE IoT Data Ecosystem**

- Charge Management Controller
- Firmware Versions
- Comms Interface
  - to EV
  - to Payment Gateway
  - to EV Network Provider
- CCS and/or NACS Protocols
  - DIN SPEC
  - ISO 15118-2, -20
- OCPP - Open Charge Point Protocol

EV – EVSE Interoperability Key to Charger Reliability

FINDING A CHARGER	ACCESSING A CHARGER	STARTING A CHARGE	COMPLETING A CHARGE

CHARGE ATTEMPT ▸ START OF POWER TRANSFER ▸ END OF POWER TRANSFER ▸ DISCONNECT

ELECTRIC VEHICLE PARKING ONLY

▲ authorize ▼

▼ plug-in ▼

power delivery ◂ event ▸

Source: **CHARGEX** consortium

LOCATION ACCURACY	WAIT TIME	CHARGE START SUCCESS*	CHARGE END SUCCESS*
		CHARGE START TIME*	EXTENDED CHARGE TIME
		SESSION SUCCESS*	
		FIRST-TIME SESSION SUCCESS	
		VISIT SUCCESS	

EV – EVSE Interoperability, Communication & Conformance Testing

The Combined Charging System (CCS) Standard and Eco-System

2010: ISO 15118 Initiated	2013: ISO 15118 Published	2014: Plug and Charge Added	2017: ISO 15118-2 Ed 2	2022: ISO 15118-20 Published	2024: ISO 15118-2 Ed 2 Published?
		Adds TLS 1.2	Unpublished Bi-directional Schema: Implemented by some vendors	Bi-directional; TLS 1.3; new Schema	Bi-Directional TLS 1.2

DIN SPEC 70121-2012 and 2014

In lieu of ISO 15118

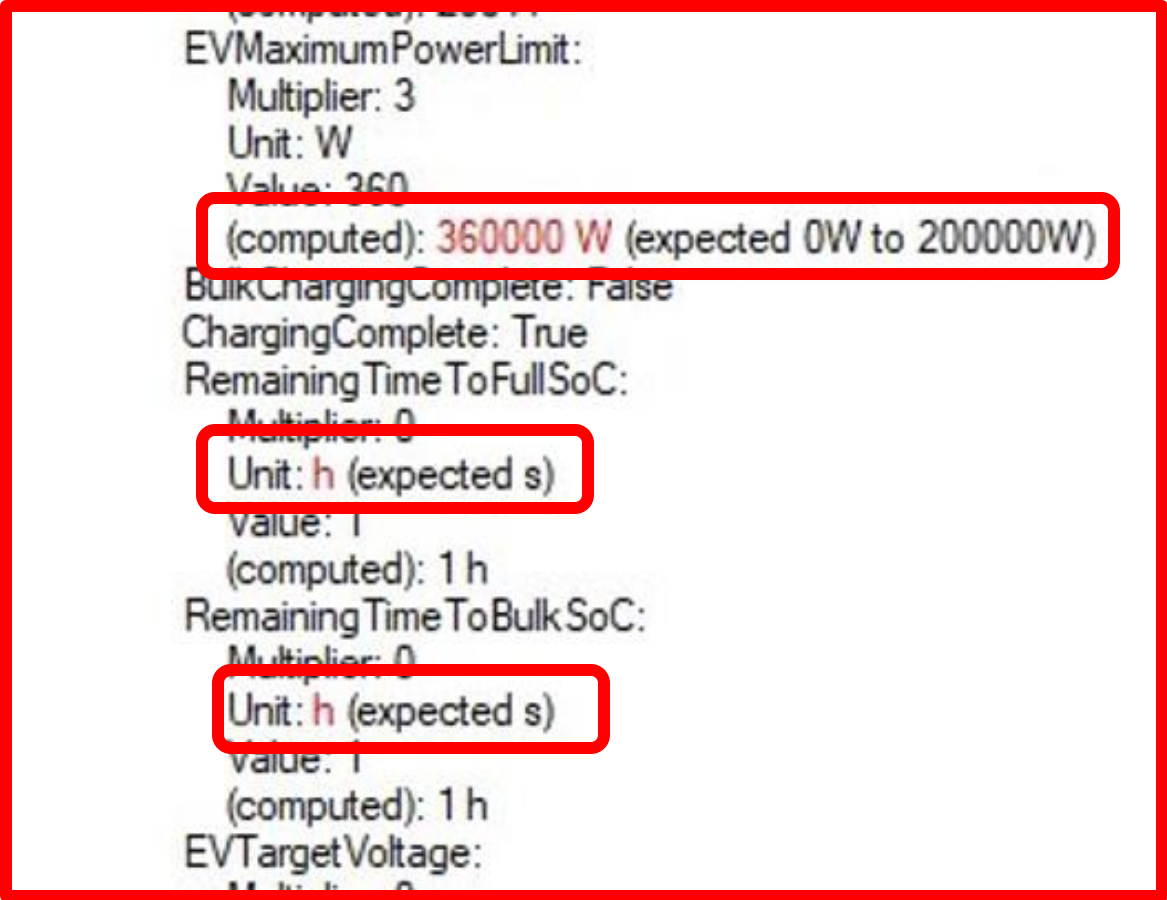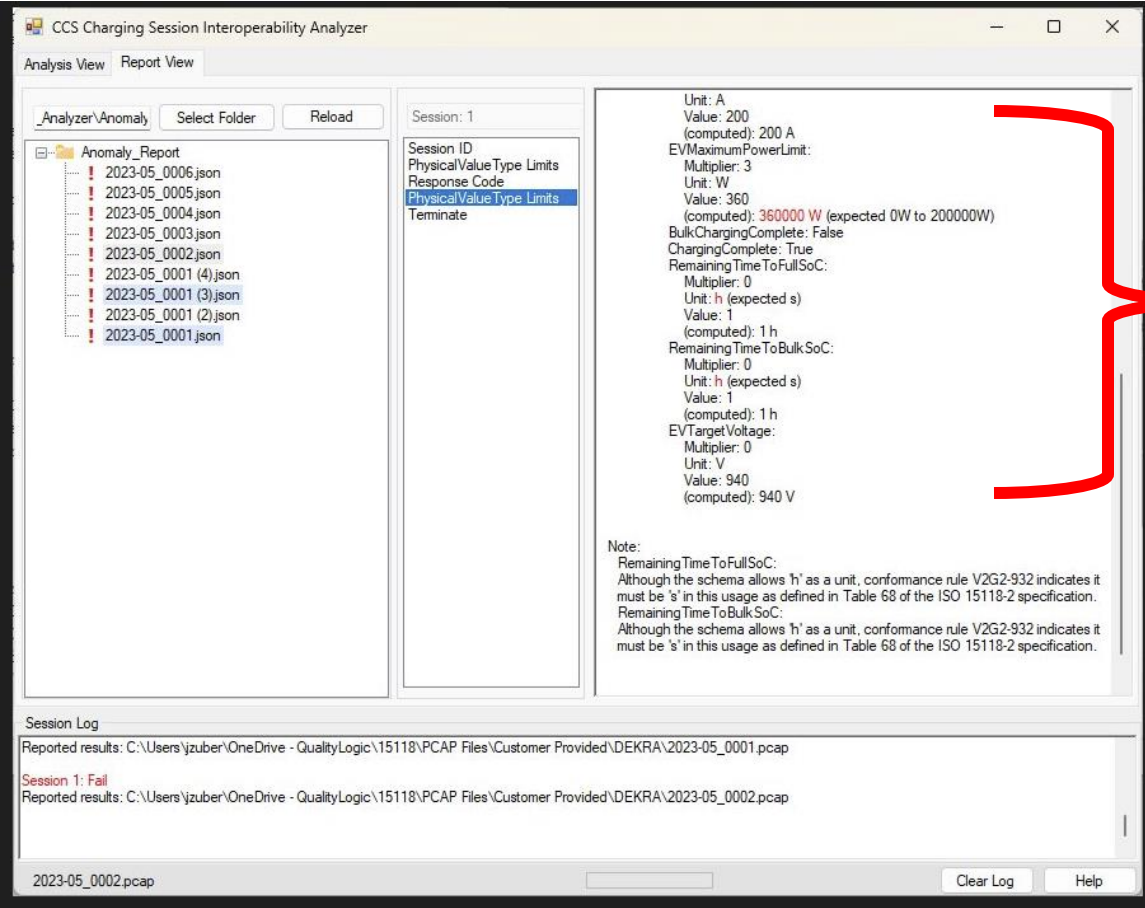| 2015: CharIn Founded	2014: Test Symposiums Started	2016: Volvo, Tesla Join	2017: Toyota Joins	2019: First CharIn Testival, Arnhem
	12 between 2014-2019			20 completed or planned through 2024

Why Do Interop Problems Exist

Conformance, Interoperability, and Certification

Why Do Interop Issues Occur?

Conformance vs Interoperability

Conformance Testing

- Ensures that an EV or EVSE conforms to the required standard – e.g. ISO 15118-2.

- It is done using a detailed test specification and tools that simulate one side of the charging interactions to evaluate the unit under test for conformance.

Interoperability Testing

- Pairs real EVs with EVSEs to validate that they work together or, if not, identify the issues that cause interoperability. This is a normal part of technology maturity.

- Testing is done in a formal event like a Testival or at the EV or EVSE OEM facility or at a field EVSE location.

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Conformance, Certification vs Self-Testing

- **Advanced technology eco-systems use independent test labs like UL, Intertek, TUV, DEKRA, and others to "certify" through a rigorous process that a product meets the required standard(s).**

- **The auto industry has a long and successful history of self-certification of safety systems BUT**

- **A very short history of interoperability with systems they don't control – e.g., a charging network.**

- **Self-certification contains interoperability risks:**
  - Lack of independent verification of conformance
  - Opportunity to ignore standards they don't agree with

- **We use the term "conformance" to mean some assurance that the product conforms to the specification beyond "trust me".**

The CCS Model for Interoperability

Complexity, lack of conformance certification, and more

# Achieving Interoperability Through Bi-Lateral Testing (Brute Force)?

- **Typical eco-system interoperability uses plugfests to**
  - Validate conformance and interoperability test cases for use in automated test systems
  - Improve both the standard and the testing standard for it

- **In lieu of Conformance certification testing, CCS is attempting to achieve interoperability through lots of 1-1 and plugfest testing events.**
  - Is this the most efficient method of achieving interoperability? And, at what cost?

- **Costs of "Brute Force" interoperability**
  - Time-consuming and expensive
  - Slows interoperability achievement
  - Becomes unwieldy to scale
  - Fixes are bi-lateral one-off vs community improvements

The Impact of Certification on Interoperability Maturity

- **Conformance certification creates a baseline for all players and speeds maturity. Interoperability testing ensures interoperability maturity.**

- **Interoperability testing only is much slower to achieve maturity**

Interoperability Maturity

Legend:
- Certification + Interop
- BF Interop Only

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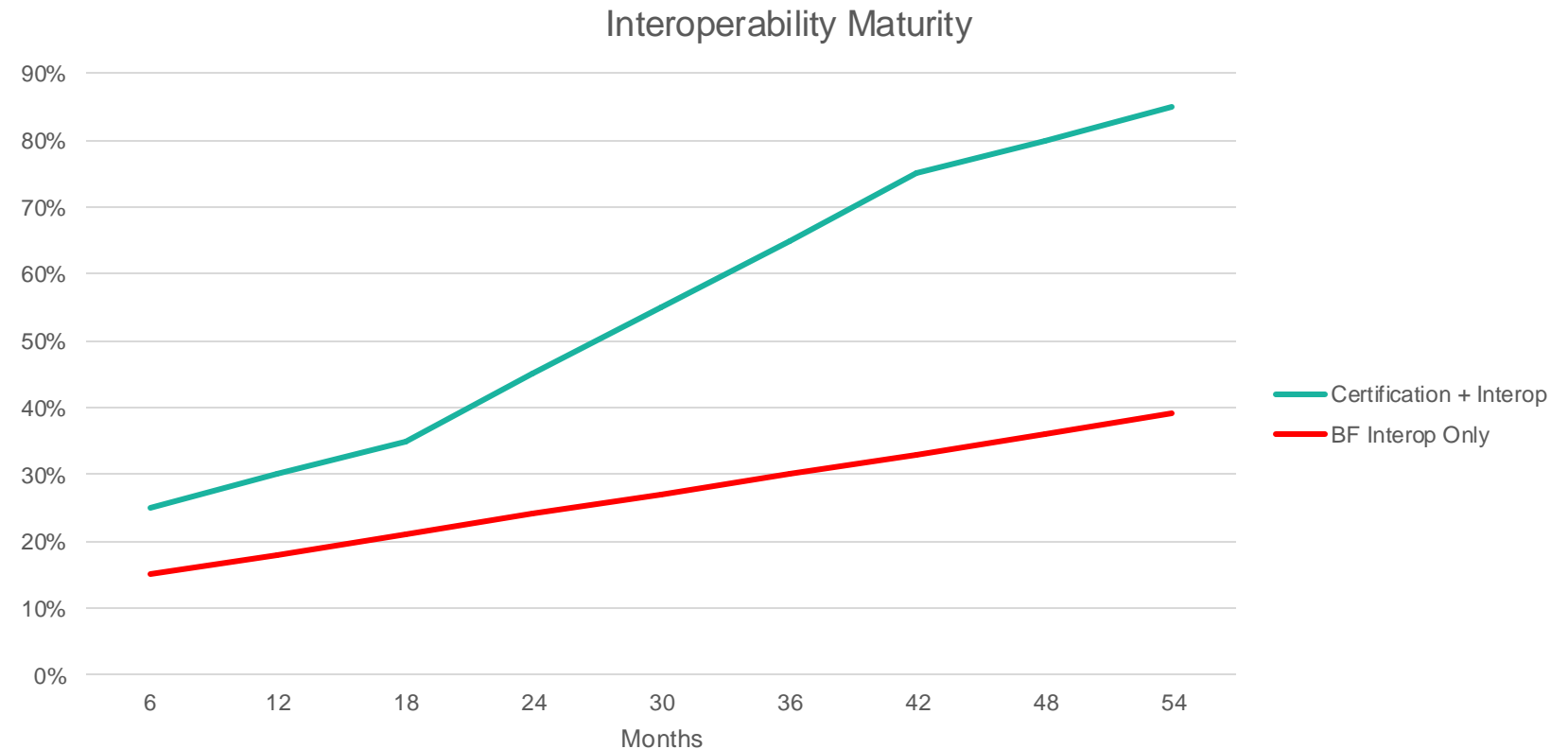
It's Only Going to Increase in Complexity

- More OEMs implement the full -2 and PnC

- More vendors enter the domain

- -20 implementations become more common

- The industry attempts to adopt NACS

- OEMs implement wireless charging and communications

- Medium and Heavy-duty vehicles implement MCS

- Vendors implement V1G and V2G support

The CCS Standard and Interoperability Challenges

The Critical Standard (and Challenge) for EV Adoption

Interoperability State of the CCS Industry

How are we doing with CCS charging infrastructure interoperability?
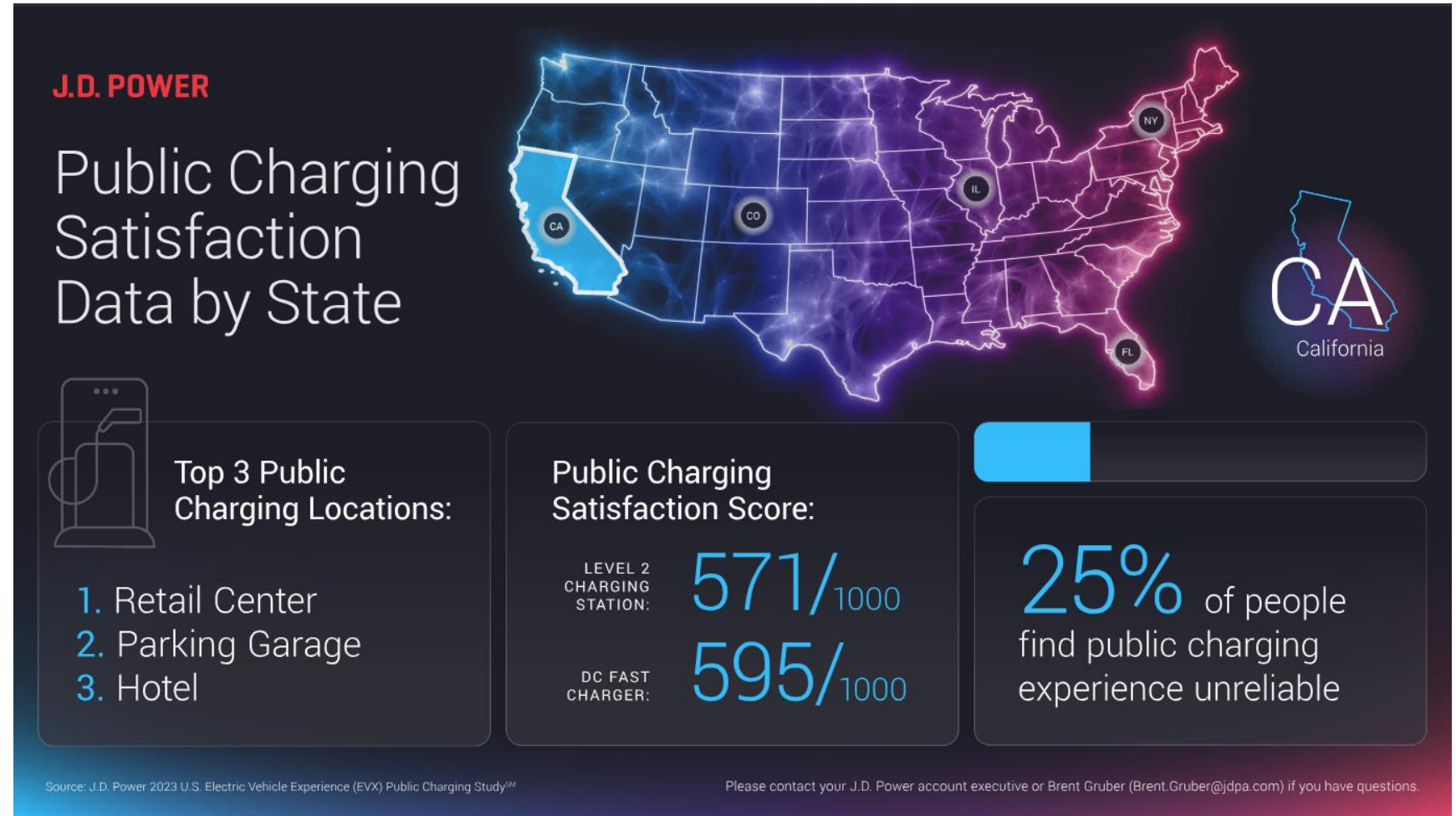
Public DC Fast Charging Unreliable

- **From Berkeley et al "Reliability of Open Public DCFC" Feb-Mar 2022**

- **Unable to charge ranged from 19% to 36.4% for top 3 Charging Networks**

- **More than 50% due to Payment system and charge initiation failures**

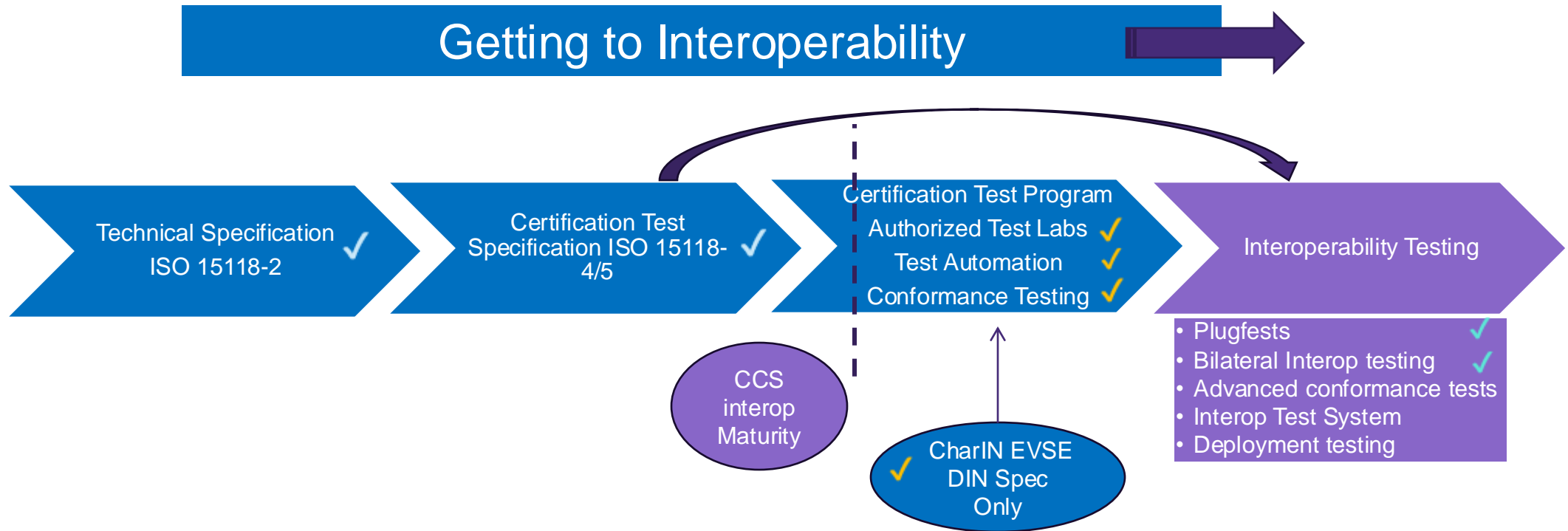Table 3. Functional State of EVSEs by the Top 3 EV Service Providers

	N	%	N	%	N	%
Functioning						
Charged for 2-minutes	21	47.7%	228	60.2%	120	55.6%
Occupied by EV and charging	6	13.6%	52	13.7%	37	17.1%
Total	27	61.4%	280	73.9%	157	72.7%
Not Functioning						
Connector broken	0	0.0%	2	0.5%	3	1.4%
Blank or non-responsive screen	4	9.1%	13	3.4%	5	2.3%
Error message on screen	4	9.1%	17	4.5%	3	1.4%
Connection error	0	0.0%	0	0.0%	6	2.8%
Payment system failure	3	6.8%	25	6.6%	16	7.4%
Charge initiation failure	5	11.4%	15	4.0%	22	10.2%
Total	16	36.4%	72	19.0%	55	25.5%
Station Design Failure						
Cable would not reach	1	2.3%	27	7.1%	4	1.9%
TOTAL	44	100%	379	100%	216	100%

Public Charging Satisfaction Drag on EV Sales

- **"…public Level 2 charging has declined to 617 (on a 1,000-point scale), 16 points lower than a year ago…"**

- **Major issues are charging speed, location and charging failures: 1 in 5 visits result in not charging.**

- **JD Power 2023 US EV Experience Public Charging Study, Aug 2023.**

J.D. POWER

Public Charging Satisfaction Data by State

Top 3 Public Charging Locations:
1. Retail Center
2. Parking Garage
3. Hotel

Public Charging Satisfaction Score:

LEVEL 2 CHARGING STATION: 571/1000

DC FAST CHARGER: 595/1000

CA California

25% of people find public charging experience unreliable

Source: J.D. Power 2023 U.S. Electric Vehicle Experience (EVX) Public Charging Study℠

Please contact your J.D. Power account executive or Brent Gruber (Brent.Gruber@jdpa.com) if you have questions.

State of CCS Interoperability

Getting to Interoperability

| Technical Specification ISO 15118-2 ✓ | Certification Test Specification ISO 15118-4/5 ✓ | Certification Test Program
Authorized Test Labs ✓
Test Automation ✓
Conformance Testing ✓ | Interoperability Testing |

- Plugfests ✓
- Bilateral Interop testing ✓
- Advanced conformance tests
- Interop Test System
- Deployment testing

CCS interop Maturity

✓ CharIN EVSE DIN Spec Only

EV Comms Certification Programs and Maturity

Standard	Certification Program(s)	Owner	ATLs	Certified Products	Interop Maturity
OpenADR	OpenADR 2.0a/b	OpenADR Alliance	10	>200	
IEEE 1815 (DNP3)	DNP3	DNP3 Users Group	1	11	
IEEE 2030.5	CSIP	SunSpec Alliance	11	66	
ISO 15118	ISO 15118-4/5	CharIN	2	1	
OCPP	OCPP 1.6	OCA	6	200	
CHAdeMO	CHAdeMO	CHAdeMO	7	>400	
SunSpec Modbus	SunSpec Modbus	SunSpec Alliance	11	69	
IEEE 1547.1	UL 1741 SB	OSHA	11	>100	
802.11	Wifi Certified	Wifi Alliance	12	~70,000	

The Process of Analyzing Interoperability Charging Sessions Today

Process and Tools for Interoperability Testing and Analysis

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Today's CCS Session Analysis Tools

Engineering Test System

- Simulates EV or EVSE
- Evaluates Conformance – not designed for interoperability Analysis
- Custom test cases
- Man-in-middle session capture and display
- $$$S, requires skilled engineer
- Lab equipment, not portable

Man-in-middle HW

15118 Sniffer/Capture

- Session capture and display
- HW specific session traffic
- Limited analysis
- Requires skilled engineer

Skilled Engineer

- Knows DIN, 15118, SLAC, etc
- Experienced with Wireshark, sniffers and other tools
- Understands implementation nuances

Wireshark PCAP file

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Reliance on Skilled Engineers

Skilled Engineer

- **Knows DIN, 15118, SLAC, etc**
- **Experienced with Wireshark, sniffers and other tools**
- **Understands charging anomalies**
- **Scarce resource**
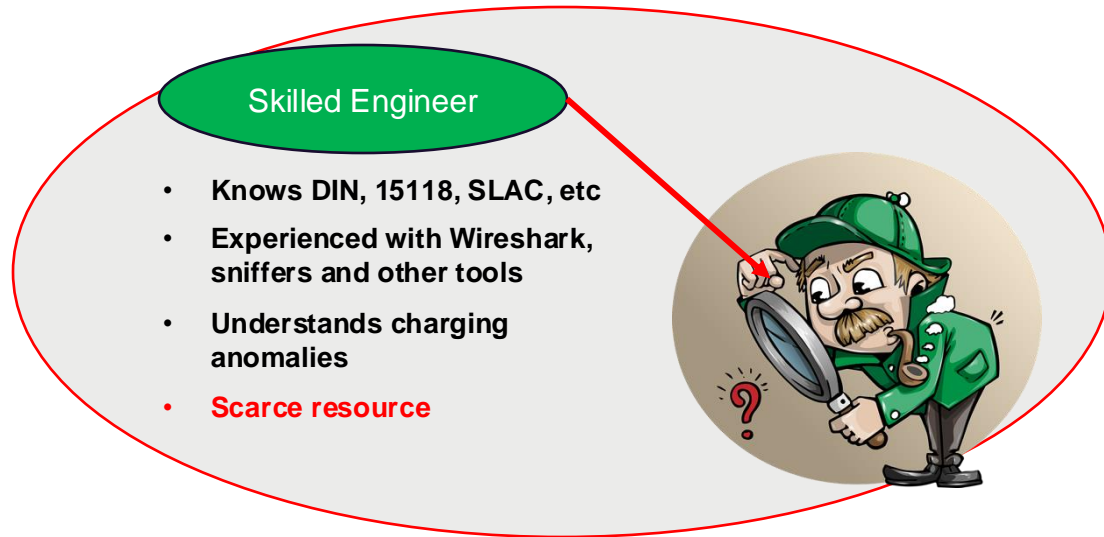
- **Skilled Engineer's Tasks**

- Conduct Interop tests and capture message traffic

- Analyzes failed or aborted charging sessions to identify cause

- Reviews PCAP files in Wireshark (or views raw PLC logs)

- Develops reports and communicates findings

- May analyze timings to support benchmarks

- Runs regression tests on firmware release candidates

- Supports field techs as needed

- Ignores successful sessions even though there is valuable information there

Demo – Christian

- **Demo of manual analysis process of PCAP files**
  - Identifying the root cause
  - Extracting timing statistics

Manual Analysis Output

Manual Charging Session Analysis Use Cases

- **Initial screening for Interop causes in failed charging sessions**
    - Deep dive into possible causes to determine specific failure causation
    - Determine where the failure originates – EV and EVSE
    - Identify potential fixes

- **Document Interop issues for further analysis, discussion and remediation strategy**

- **Capture timing statistics to support benchmarking of chargers and EVs**

- **Conformance testing issue identification**

- **Analysis of regression test charging sessions prior to firmware release**
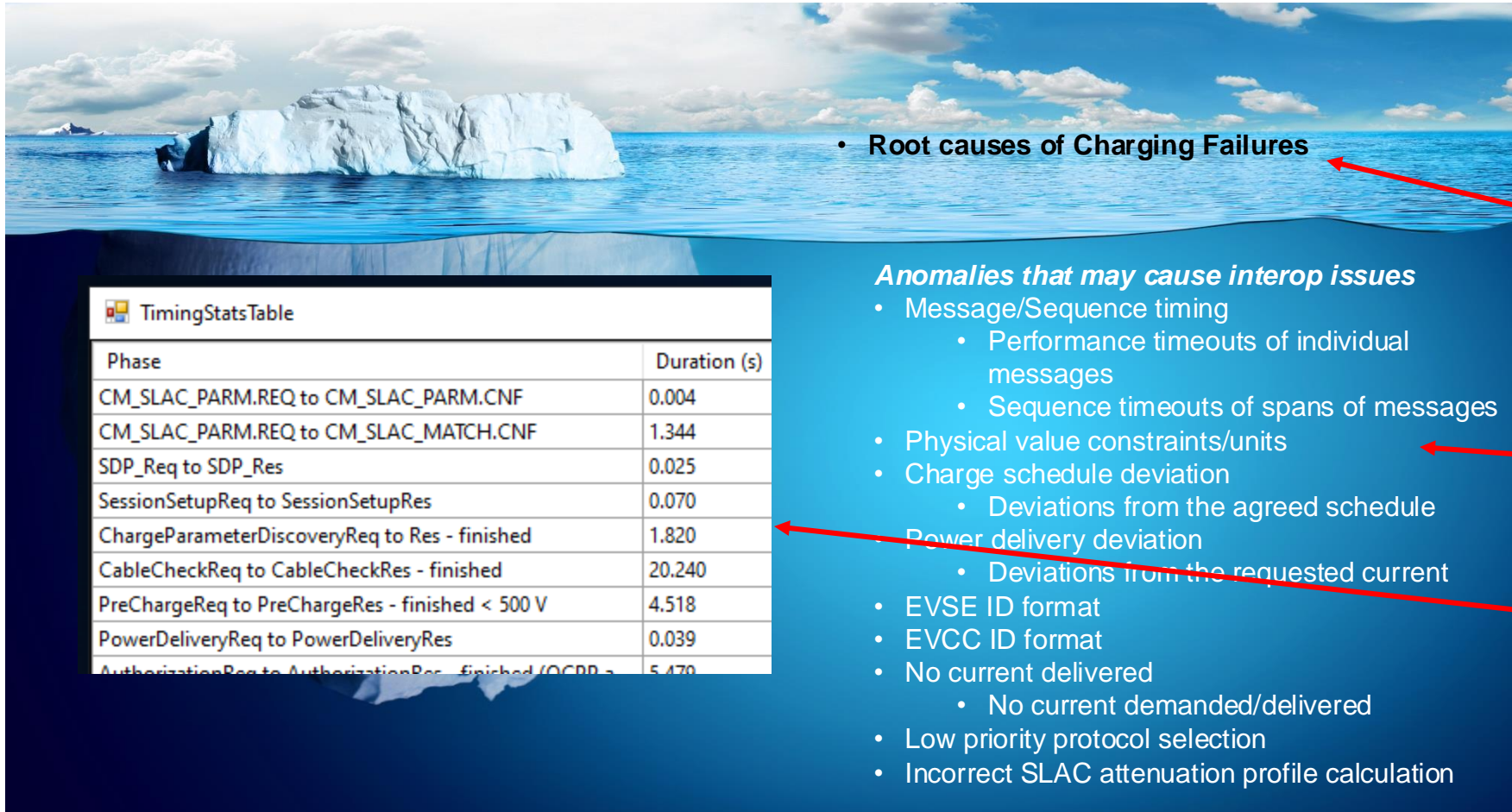
The Analysis Gap – What Are We Missing

Valuable information hidden from today's Interop Process

What Are We Missing Today?

- **Demo of some examples of what is missed in manual analysis.**
    - Anomalies discovered after finding the root cause
    - Anomalies found in successful charging sessions

The Information Gap in Today's Charging Session Analysis Process

Root causes of Charging Failures

Anomalies that may cause interop issues
- Message/Sequence timing
  - Performance timeouts of individual messages
  - Sequence timeouts of spans of messages
- Physical value constraints/units
- Charge schedule deviation
  - Deviations from the agreed schedule
- Power delivery deviation
  - Deviations from the requested current
- EVSE ID format
- EVCC ID format
- No current delivered
  - No current demanded/delivered
- Low priority protocol selection
- Incorrect SLAC attenuation profile calculation

TimingStatsTable

Phase	Duration (s)
CM_SLAC_PARM.REQ to CM_SLAC_PARM.CNF	0.004
CM_SLAC_PARM.REQ to CM_SLAC_MATCH.CNF	1.344
SDP_Req to SDP_Res	0.025
SessionSetupReq to SessionSetupRes	0.070
ChargeParameterDiscoveryReq to Res - finished	1.820
CableCheckReq to CableCheckRes - finished	20.240
PreChargeReq to PreChargeRes - finished < 500 V	4.518
PowerDeliveryReq to PowerDeliveryRes	0.039
AuthorizationReq to AuthorizationRes - finished (OCPP a	5.470

- Typical root causes identified in 10-30 min by manual analysis of the charging session PCAP file

- Hidden issues found with automation, identified in seconds. Not usually identified due to time.

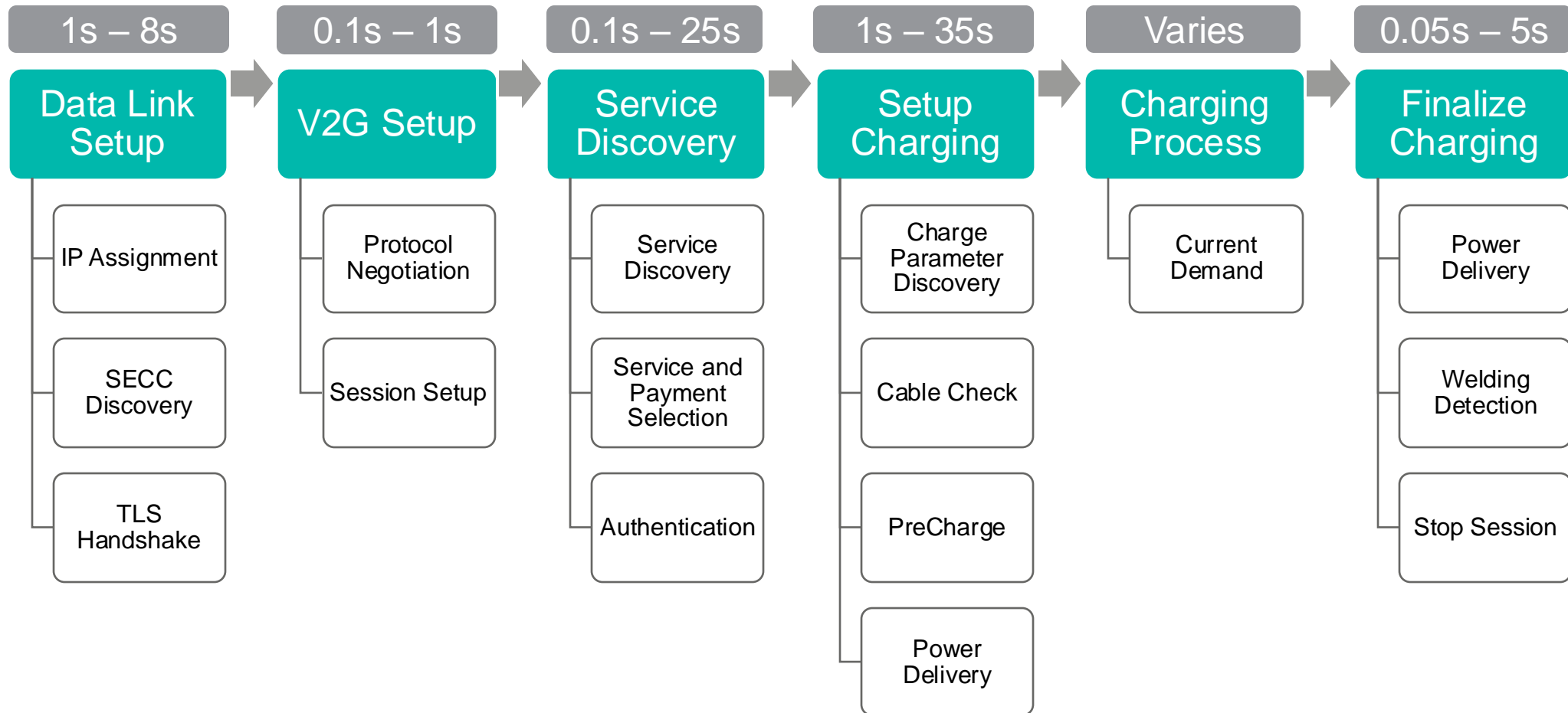- Timing statistics not extracted due to time constraints

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Top 10 Interop Issues Observed

	Anomaly	Occurrences	Ease of Detection
1	V2G State Transition	86	Moderate
2	Session Termination	79	Easy
3	EV Target Power Demand	60	Moderate
4	EVSE ID	51	Moderate
5	Physical Value Constraints	44	Hard
6	No Current Delivered	35	Hard
7	SLAC State Transition	28	Moderate
8	EV Target Voltage	23	Moderate
9	FAILED Response Code	21	Easy
10	Message Timeout	19	Moderate

– Data collected from 317 capture files

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CCS Charging Communication Stages With Timings

1s – 8s	0.1s – 1s	0.1s – 25s	1s – 35s	Varies	0.05s – 5s
Data Link Setup	**V2G Setup**	**Service Discovery**	**Setup Charging**	**Charging Process**	**Finalize Charging**

Data Link Setup
- IP Assignment
- SECC Discovery
- TLS Handshake

V2G Setup
- Protocol Negotiation
- Session Setup

Service Discovery
- Service Discovery
- Service and Payment Selection
- Authentication

Setup Charging
- Charge Parameter Discovery
- Cable Check
- PreCharge
- Power Delivery

Charging Process
- Current Demand

Finalize Charging
- Power Delivery
- Welding Detection
- Stop Session

Solving the Analysis Gap by Automating It

Improved Interoperability Testing and Analysis

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How to Make Interoperability Testing More Efficient?

- **If we assume conformance certifications will not be ubiquitous anytime soon, how do we accelerate interoperability testing effectiveness?**

- **Potential Interop Improvement strategies:**
  - Improve interoperability test model – from Ad Hoc to Strategic Interop testing
  - Improve interoperability test tools to automate analysis of root cause and other issues
  - Permanent interop facilities such as Elaad NL, ACM, CEC Charge Yard
  - Remote interoperability testing

- **Meanwhile, accelerate certification testing**
  - Include both EVSE and EV OEMs
  - Develop strong incentives for voluntary certifications
  - Support regulatory mandates

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Manual Analysis vs Automated Session Analysis

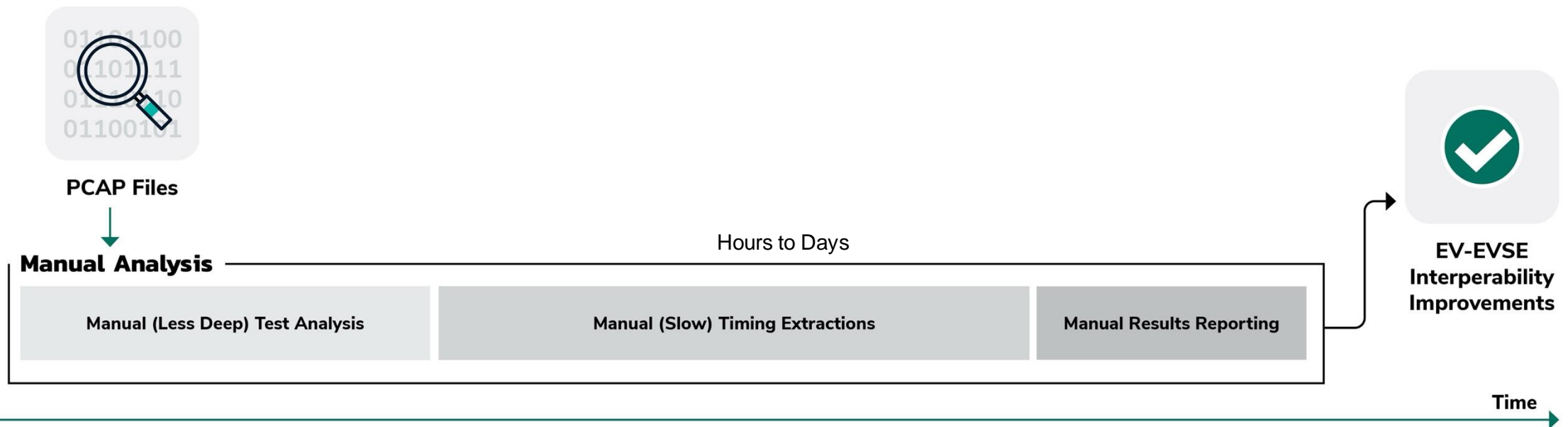## Manual Charging Session Analysis Use Cases

- **Initial screening for Interop causes in failed charging sessions**
    - Deep dive into possible causes to determine specific failure causation
    - Determine where the failure originates – EV and EVSE
    - Identify potential fixes

- **Document Interop issues for further analysis, discussion and remediation strategy**

- **Capture timing statistics to support benchmarking of chargers and EVs**

- **Conformance testing issue identification**

- **Analysis of regression test charging sessions prior to firmware release**

CCS Analyzer Use Cases – Automated CCS Analysis

- **All current manual use cases PLUS**

- **Much faster analysis of PCAP files**

- **Enabling less experienced engineers to conduct analysis of charging sessions including service technicians**

- **Integration into development tool chain**

- **Automated collection of successful charging session interop and timing data (typically not analyzed due to time)**

- **Quick look at potential EV-EVSE interop issues in end-end charging failures**

- **Aggregation of charging session data for trend analysis**

- **Aggregation of timing statistics and automated benchmarking**

- **Real-time analysis of charging sessions**

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Today's Analysis Speed

Manual, Slow, Uncovers "Tip of the Iceberg"

PCAP Files

Hours to Days

Manual Analysis

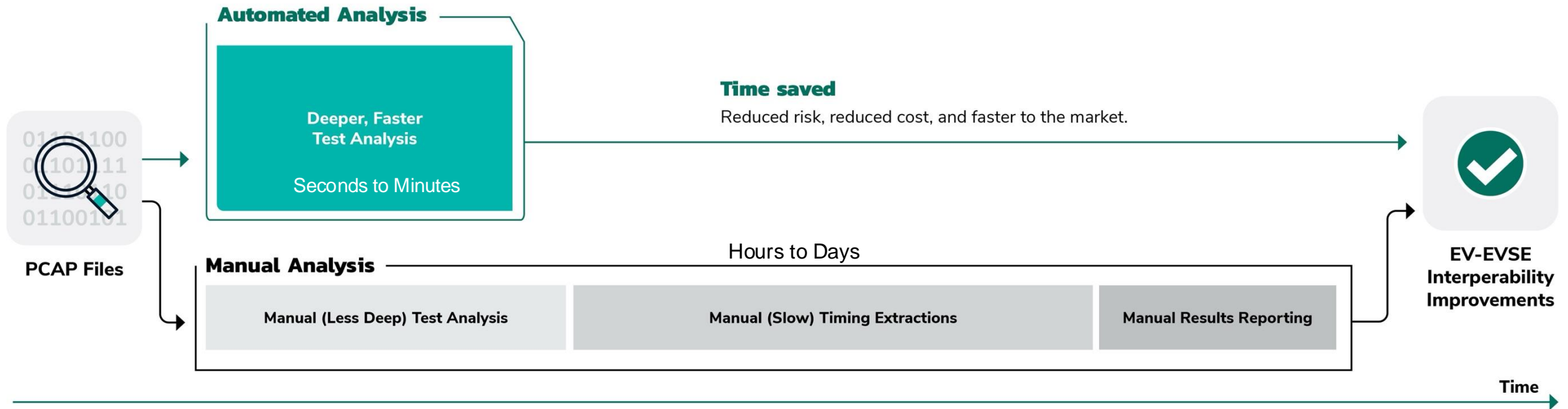| Manual (Less Deep) Test Analysis | Manual (Slow) Timing Extractions | Manual Results Reporting |

EV-EVSE Interoperability Improvements

Time

AND, repeat interoperability testing forever to:
- test legacy EV / EVSE firmware releases & new standards

Next Generation

Faster, Deeper, Smarter EV - EVSE Interoperability Testing

Automated Analysis

Deeper, Faster
Test Analysis

Seconds to Minutes

Time saved
Reduced risk, reduced cost, and faster to the market.

PCAP Files

Manual Analysis

Hours to Days

| Manual (Less Deep) Test Analysis | Manual (Slow) Timing Extractions | Manual Results Reporting |

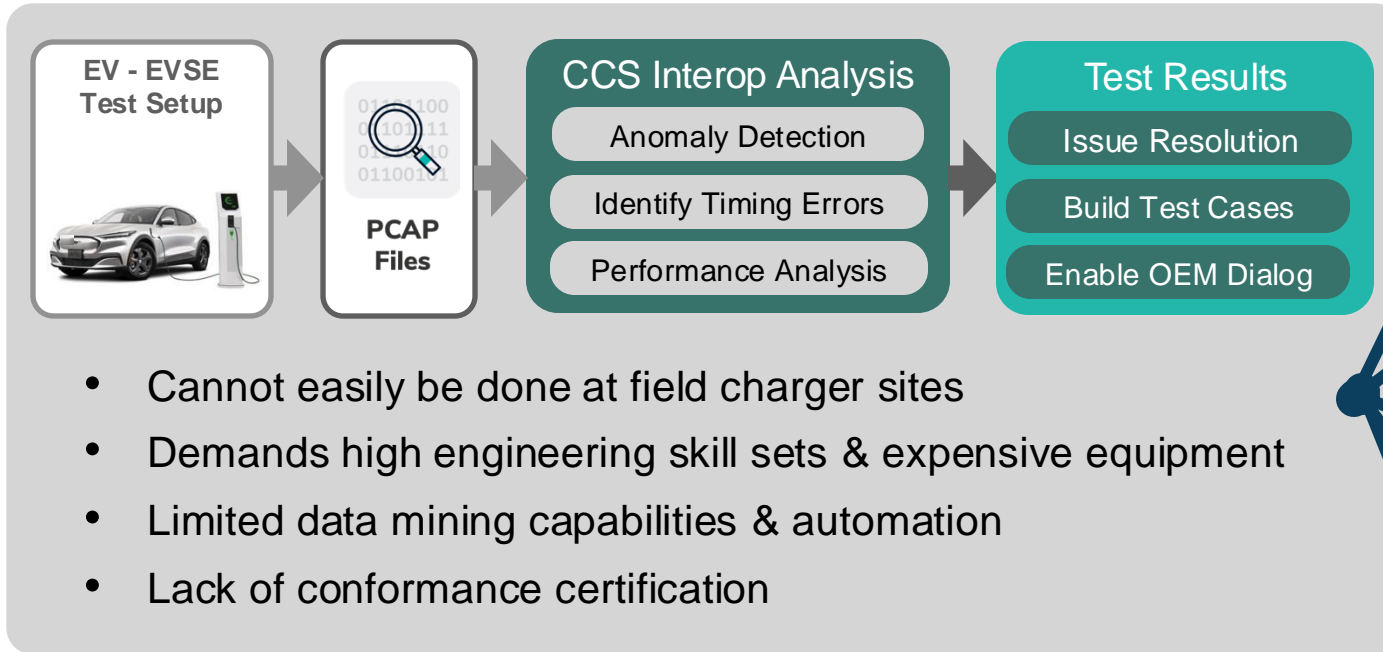**EV-EVSE
Interperability
Improvements**

Time

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The Future of CCS Interoperability Testing Analysis

Improved tools, AI, and more

The Future: EV – EVSE Interoperability Testing

Today's Interop Testing

EV - EVSE Test Setup → **PCAP Files** →

CCS Interop Analysis
- Anomaly Detection
- Identify Timing Errors
- Performance Analysis

→

Test Results
- Issue Resolution
- Build Test Cases
- Enable OEM Dialog

- Cannot easily be done at field charger sites
- Demands high engineering skill sets & expensive equipment
- Limited data mining capabilities & automation
- Lack of conformance certification

Future Interop Testing

Real-Time Field Testing
- Enable remote resolution of real-time charging issues
- Embedded EVSE self-diagnosis of interop issues

AI-Driven Interop Insights
- Intelligent automation of test data analysis
- AI & machine learning improves with each iteration

New Tools to Automate Interop Process
- Automated analysis to reduce engineering time
- Improved simulation of real-world EVs and EVSEs

Scaled Data Trend Analysis
- Test result data lakes enable critical mass for analysis
- Extract pattern data from large charge session data sets

EV, EVSE Product Development
- Leverage test data to inform original product design
- End-end interoperability and performance analysis

Thank You

- **If you have questions on the topics in this webinar, please contact us at info@qualitylogic.com**

- **For information on QualityLogic's Tools and Services, contact info@qualitylogic.com**

- **Please provide feedback on the concept of a training workshop on analyzing CCS Charging Sessions.**

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Questions?

If you want to know more, email jmater@qualitylogic.com

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