Innovate Sustainable Mobility

Accelerate Your Vehicle Development.
Optimum Performance of New CASE Technologies

TURN NEW BUSINESS MODELS AND DIGITAL TRANSFORMATION INTO PROVEN VALUE AND ROI

- Engineer high-performance batteries and lightweight designs that go the distance without sacrificing cost
- Experience, and validate on the production process early
- Sensing, connecting, and reporting for a safer driving experience
- Reach optimal passenger comfort and energy consumption
Get Sustainable Mobility Right the First Time

EARLY AND CONTINUOUS FOCUS ON VEHICLE PERFORMANCE WITH VIRTUAL PROTOTYPING AND HYBRID TWIN

• From vehicle engineering, manufacturing, and assembly operations to service process engineering & maintenance
• Define and deliver safe and reliable vehicles and production processes
• Achieve highest product quality and life-time performance reducing the reliance on physical prototypes

ESI’s commitment to Automakers

FIAT CHRYSLER
FORD
GESTAMP
HONDA
RENAULT NISSAN
VOLKSWAGEN
ZF AUTOMOTIVE
...

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5 Main Automotive Challenges

1. Multi Material Joining & Assembly
2. Electrification & Battery
3. Smart Safety
4. Smart Operator 4.0
5. Smart Cabin

Secure Delivery & Lightweight Body & Chassis
Supporting EV and Battery market Challenges
Safe Driving Vehicle Operations & Autonomous
Towards Efficient Product Assembly Line
New Passenger Experience
A Paradigm Shift
Towards Zero Downtime With Zero Physical Tests And Prototypes

PLM
Product Lifecycle Management
Focus is on PRODUCT

PPL
Product Performance Lifecycle™
Focus is on lifetime PERFORMANCE

Achieve Real Results, Virtually
Can You Currently Make the Right Decisions?

**SEQUENCIAL MANUAL WORKFLOW IN THE INDUSTRY**

- Design
- Vehicle Engineering
- Reliability Engineering
- Vehicle Validation & Certification
- Prototypes
- Pre-Series
- Industria-
- Manufacturing Engineering
- Tooling Validation
- Vehicle In-
- service

**DIGITAL WORLD**

**PHYSICAL WORLD**

5a. One current trend in automotive industry is to have engineering and manufacturing departments working closely together as early as possible. Is this trend also happening in your company?

- Yes 100%
- No 0%

5b. Are dedicated initiatives/KPI's in place to support this trend actively?

- Yes 33%
- No 67%

Non-representative ESI survey amongst decision-makers in the auto manufacturing space 3/21
Bridging Engineering and Manufacturing Worlds

Design to Manufacturing
- Design right the 1st time
- Make decisions earlier and with higher confidence
- Reduce late manufacturing loops
- Minimize body & chassis manufacturing lead time

Virtual Test With Virtual Prototypes
- Evolve towards zero physical prototypes to substantially decrease lead time and cost
- Overall reduced vehicle to market lead time while increased ROI

No Unexpected Downtime
- Achieve maximum range without sacrificing comfort, safety, or cost

BLENDING VIRTUAL AND PHYSICAL – THE ART OF DECISION MAKING @ESI

VIRTUAL PROVING GROUND + PILOT ASSEMBLY HALL + SERVICE MAINTENANCE GARAGE

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Single Core Model Increases Process Efficiency

One Source of Truth for All Development Teams

- CAD
- PDM System
- Single Core Model
- Virtual Manufacturing & Assembly
- DESIGN
- MASTER ASSEMBLY
- DOMAIN ASSEMBLY
- LOAD CASE ASSEMBLY
- 1 MULTI-DOMAIN SOLVER
Make the Right Decision at the Right Time for Your Asset
Make a Difference with the Hybrid Twin

Virtual Prototyping
Model Order Reduction

System Model

HYBRID TWIN

VIRTUAL TWIN

DIGITAL TWIN

Physics-based Model
Data-driven Model

Data Analytics
Real Data
Machine Learning

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Multi-Material Joining and Assembly of Chassis & Body

Topics
- Product Design
- Performance Engineering
- Parts Manufacturing
- Assembly Manufacturing
Spotlight on Pain Points

OEM’S AND TIER 1 SUPPLIERS MUST SOLVE THE MULTI-PROCESS AND MULTI-JOINING CHALLENGE

• Increasing demand for lightweight vehicles
  • linked to CO² emissions reduction
  • improvement of range for electrified vehicles
  • high demand for multi-material
• Multiplication of body variants increases complexity of manufacturing strategies
• Growing need to reduce physical prototyping cost in pre-production
• Ever rising quality standards

• Manufacturing & Assembly process digitalization as a key driver for answering those challenges
Adapt and Improve Workflows and Methodologies

**CURRENT OEM WORKFLOW**

- **Design**
- **Performance Engineering**
- **Prototypes**
- **Pre-series**
- **Industrialization**

**VIRTUAL WORLD**

- Early Concept Decision
- Mass / cost / feasibility
- Fast, accurate & robust performance validation
- Early decision making
- Accurate performance prediction
- Anticipating issues and adjustments
- Seamless information transfer and chaining

**PHYSICAL WORLD**

- Feasibility assessment
- Definition of process
- Forming history to perf.
- Assembles process definition (experts knowledge)
- Assembly try-outs and adjustments loops
- Physical validation and correlation
- Ensure continuous quality

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Saving Potential in Conventional BiW Assembly

### CURRENT OEM WORKFLOW

- **Design**
- **Performance Engineering**
- **Prototypes**
- **Pre-series**
- **Industrialization**
- **Manufacturing and Assembling**
- **Adjustments**

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**VIRTUAL WORLD**

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**PHYSICAL WORLD**

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- **40,000,000 $** per car program globally and annually: Total physical try-out cost for BiW assembly validation
- **10,000,000 $** cost per program: Dimensional & perceived quality between body shop and trim / final assembly
- **3,000,000 $** cost globally: Automotive geometrical & perceived quality
- **2,000,000 $** cost per program: Body shop corrections & mitigations due to dimensional issues
- **2,000,000 $** cost per program: Cost of Logistics and Human Resources
- **1,000,000 $** cost per year: Cost of Physical prototypes for performances testing
- **100,000 $** cost per resource: Full time employee added to the line for manual corrections
- **40,000 $** cost per geo. fit issue: Analysis and correction of one sample geometrical fit issue at the line
- **35,000 $** cost per clamp: Two additional clamps added to an assembly fixture
  - **+$$$** 2-3 customer claims per year due to geometrical issues
  - **+$$$** Cost for dimensional & perceived quality issues reaching trim & final can be even higher than body shop costs

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**Spotlight On Multi-Material Joining and Assembly**
Digitalization Towards End-to-end Virtual Prototyping

MOVE TOWARDS ZERO
REDUCE RELIANCE ON PHYSICAL PROTOTYPE FOR DECREASED LEAD TIME AND COST
4 Key Domains For Body/Chassis Assemblies

1. **Product Design**
   Definition of the new product design, architecture and **concept decision**

2. **Performance Engineering**
   Optimization and **validation** of the product performances **as manufactured**

3. **Parts Manufacturing**
   Definition and **accurate** validation of the single part manufacturing, **optimization** of the process parameters

4. **Assemblies Manufacturing**
   Evaluation of joining technology and **validation** of the **assembly dimensional quality** (tolerances and perceived quality criteria)
How ESI Chained Solutions **Shorten Time to Market**

**Paradigm Shift**

- **Virtual World**
  - Design
  - Performance Engineering
  - Manufacturing and Assembling

- **Physical World**
  - Pre-series
  - Industrialization

**Product Design**

- Ensure feasibility of new design

**Segments**

- Doors and Closures
- Body In White
- Chassis

*Estimate manufacturing feasibility as support for early decisions*
Early Manufacturing Feasibility Analysis

ESTIMATE MORE ACCURATELY THE FEASIBILITY OF A NEW DESIGN FOR EARLY DECISION MAKING

• Evaluate stamping operations without tooling definition
• Bring more accuracy to part cost estimations
• Anticipate critical manufacturing road blocker since the beginning of the project
How ESI Chained Solutions **Shorten Time to Market II**

**PARADIGM SHIFT**

<table>
<thead>
<tr>
<th>Virtual World</th>
<th>Physical World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>Pre-series</td>
</tr>
<tr>
<td>Performance Engineering</td>
<td>Industrialization</td>
</tr>
<tr>
<td>Manufacturing and Assembling</td>
<td></td>
</tr>
</tbody>
</table>

**Product Design**

Ensure feasibility of new design

- Doors and Closures
- Body In White
- Chassis (Segment 1)

**Performance Engineering**

Predict Manufacturing & Joining process effects on Crash performance

"..." on Fatigue performance
Validate BiW & Chassis Performance as Manufactured

MULTI DOMAIN, END-TO-END APPROACH BY CHAINING FORMING & WELDING EFFECTS TO PERFORMANCE EVALUATION

• More confidence in performance evaluation by mapping manufacturing effects
• Avoid unforeseen cracks in late-stage prototype crash test
• Ensure failure prevention in service life
“The consistent chaining of virtual manufacturing results and virtual performance for crash and safety as well as for NVH and durability is a definite technological breakthrough, ensuring the right levels of product performance for lightweight design.”

EISEI HIGUCHI  HONDA R&D
“Thanks to ESI [...] we succeeded in developing one of our new vehicles, achieving good physical tests right the first time, allowing us to earn the whole five stars on the Euro NCAP safety test, following its stricter protocol launched in 2018.”

OLIVIER COLMARD RENAULT
How ESI Chained Solutions Shorten Time to Market III

**PARADIGM SHIFT**

**VIRTUAL WORLD**

- **Design**
- **Performance Engineering**
- **Manufacturing and Assembling**

**PHYSICAL WORLD**

**Product Design**
- Ensure feasibility of new design
- Estimate manufacturing feasibility as support for early decisions

**Performance Engineering**
- Validate Performances as Manufactured
- Predict Manufacturing & Joining process effects on Crash performance
- “…” on Fatigue performance

**Manufacturing**
- Single part manufacturing
- Accurate Manufacturing
- Anticipate/control/ optimize Distortions & Perceived quality on BIW assemblies

**Assembly**
- Ensure Assembly Quality
- Anticipate/control/ optimize Distortions on Chassis assemblies

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Closures, BiW and Chassis Dimensional Accuracy

ENABLE VIRTUAL ASSEMBLY ALL ALONG THE DEVELOPMENT PROCESS

- Support assembly validation process in pre-production phase
- Reduce physical prototype testing and try outs
- Optimize the whole assembly validation process integrating virtual trials in earlier development phases
- Anticipate tooling/ fixtures definition and compensation decisions

Doors and Closures
Plan Joining and hemming processes and check the perceived quality in the Virtual Light Room

Body in White
Predict distortions to optimize the assembly process definition and reduce physical try outs

Chassis
Predict thermal welding effects and control earlier the quality of the assemblies
Groupe PSA uses virtual prototyping to make the right decisions in their casting process

**Highlights**

“There is no prototype phase in our development procedure anymore.”

**Key Performance Indicator**

robustness and reliability are key engineers are solving 98% of process manufacturing issues without the help of any simulation expert or any real prototype
Nissan reduced engineering lead times for new lightweight material by as much as 50%.
“We achieved very good results thanks to the accuracy of the simulation [and...] we able to [...] evaluate the die compensation, despite the complexity of such a case with three different thicknesses and two weld lines. “

EDUARDO SULATO & FÁBIO LICHTENTHÄLER GESTAMP
How ESI Chained Solutions Shorten Time to Market IV

**PARADIGM SHIFT**

**VIRTUAL WORLD**

- Design
- Performance Engineering
- Manufacturing and Assembling

**PHYSICAL WORLD**

- Pre-series
- Industrialization

**Product Design**

- Ensure feasibility of new design
- Estimate manufacturing feasibility as support for early decisions

**Performance Engineering**

- Validate Performances as Manufactured
- Predict Manufacturing & Joining process effects on Crash performance
- “…” on Fatigue performance

**Manufacturing**

- Accurate Manufacturing
- Single part manufacturing

**Assembly**

- Ensure Assembly Quality
- Anticipate/control/ optimize Distortions & Perceived quality
- Anticipate/control/ optimize Distortions on BIW assemblies
- Anticipate/control/ optimize Distortions on Chassis assemblies

**Indus. / In Service**

- Improve Productivity
- Assembly Operation Performances
- Hybrid Twin of Assembly Line

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Electrification & Battery

Topics
Go the Distance
Enjoy the Journey
Safety First
Green & Affordable
Build High-Performance Batteries That Go the Distance

Go the **Distance**  
Enjoy the Journey  
Put **Safety First**  
Make it **Green & Affordable**
Find the Optimal Electric Vehicle Setup

FIND THE OPTIMAL VEHICLE TOPOLOGY AND OPERATING STRATEGY IN LINE WITH RANGE REQUIREMENTS AND VEHICLE CHARACTER

• Define vehicle system requirements for all components and subsystems
• Evaluate range under various route profiles and climate conditions
• Test and optimize different operation strategies and controller settings
• Find the optimal balance between all hardware and software configurations
Pre-Experience Vehicle Performance

FIND THE OPTIMAL BALANCE BETWEEN PASSENGER BEHAVIOR, ENVIRONMENT, AND VEHICLE PROPERTIES WITH HYBRID TWIN TECHNOLOGIES

• Vehicle health monitoring, diagnostics & prognostics
• Reduce failures & unplanned down time, maintenance and operations cost
• Explore energy storage & charging capabilities
Maximizes the Driving Range and Acoustic Quality of the New e-tron

**Highlights**
Innovate aerodynamic features like enclosed air flow and virtual exterior mirrors to lower energy consumption
Virtual feature test before producing the first prototype

**Key Performance Indicator**
Reduce vehicle drag coefficient down to 0.27 - a top rating in the SUV segment
Deliver exceptional validation capabilities at the right time
Creating an Excellent Passenger Experience

Go the Distance  Enjoy the Journey  Put Safety First  Make it Green & Affordable
Remove Undesired Interior Noises

VIRTUALLY TEST AND OPTIMIZE ACOUSTIC EV PERFORMANCE TO CREATE EXCELLENT PASSENGER EXPERIENCE

• Maximize acoustic comfort level by solving new audible noise such as wind noise
  • Detect noise sources and path early in product development and optimize the design
• Create a truly enjoyable auditory experience with smooth voice-activated infotainment system interactions and individualized sound zones
Bentley optimized every component of the Flying Spur first in the virtual world before creating physical parts.
Ensure Efficient Thermal Comfort

ENSURE BOTH MAXIMUM COMFORT AND MAXIMUM RANGE

- Test different design variants and evaluate their impact on thermal comfort and on battery consumption
- Optimize HVAC, thermal and climate systems early in the development phases
Put Safety First and Make Vision Zero Come True

Go the **Distance**

Enjoy the Journey

Put **Safety First**

Make it **Green & Affordable**
KEEP UP WITH BATTERY-SPECIFIC SAFETY NORMS

DEVELOP POWERFUL BATTERY SYSTEMS THAT MEET SAFETY REGULATIONS

- Protect car occupants & pedestrians in case of emergency
  - Cell failure
  - Thermal runaway
  - Propagation
- Extend car lifespan ensuring safety and durability requirements are met
“[…] the mechanical simulation was an instrumental part in helping us get the design approved. We could not have done that without ESI.”

Dr. Matt Klein Farasis Energy
Effective Battery Thermal Management

FIND THE OPTIMUM THERMAL MANAGEMENT CONCEPT FOR THE BATTERY

• Understand battery heat generation
• Validate temperature distribution
• Run parameter studies to optimize battery cooling
  • Liquid cooling
  • Air cooling
RESEARCH STORY

upscale

Develop future advanced occupant protection systems covering main challenges of road safety with highly automated vehicles

Highlights

Upscaling product development simulation capabilities exploiting Artificial Intelligence for Electric Vehicles

Ensure batteries & full EV crash certification with accurate vehicle aero, thermal and crash modeling

Key Performance Indicator

Reduce development time by 20%

Increase vehicle performance

Image courtesy of upscaleproject.eu
Make Noise Around Silence

FIND THE OPTIMUM SOUND MIX FOR ACOUSTIC VEHICLE ALERTING SYSTEM AND ENSURE ULTIMATE PEDESTRIAN SAFETY

• Ensure compliance with requirements on pedestrian safety and injury risk functions e.g. UN R138R1
• Proof virtually that EVs are safe for pedestrians when driving silently at low speed
  • Optimize warning devices
  • Explore the interaction of acoustic warning system with surroundings
Achieve Manufacturability, Dimensional Accuracy And Operational Excellence

Go the Distance

Enjoy the Journey

Put Safety First

Make it Green & Affordable
Human-Centric Cell Design

INTEGRATE AND BUILD YOUR NEXT ELECTRIC VEHICLE AS PLANNED BY KEEPING AN EYE ON INTERACTIONS BETWEEN HUMANS, PRODUCTS AND PROCESSES

• Validate designs through eyes of operators
• Visualize concepts before they exist
• Deliver better safety and ergonomics for EV factory operations
• Increase ROI by getting electric vehicles and processes right the first time
Affordable Manufacturing of Sustainable Mobility

TOWARDS MASS ADOPTION OF NEW MOBILITY DEVICES WITH COST EFFECTIVE MANUFACTURING AND SUSTAINABLE PRODUCT VALIDATION

- Establish low impact manufacturing processes for die casting and moulding
- Define right composite process
- Get assembly distortion under control
- Ensure battery reuse for minimal environmental impact
BMW, Ford, Jaguar Land Rover, and Volkswagen count on ESI's Human Centric solution to predict the downstream impact of design decisions, validate ad-hoc design changes, and enable cross-functional teams to visualize cause and effect relationships.
Spotlight On **Smart Safety**

**Smart Safety**

**Topics**
- Passive Safety
- Active Safety
- ADAS
6 Facts Users Like Best About ESI’s Auto Solutions

THE KEYS TO ACHIEVE SMART SAFETY

• Fastest crash simulation on the market
• Best-in-class airbag models to predict inflation kinematics/forces
• Unique single-core model approach for effective team-work
• ESI’s unique expertise in material science with accurate modular material models
Maximum Passenger Protection

MAKE “VISION ZERO” COME TRUE: ULTIMATE SAFETY WITH ADVANCED AIRBAGS

• Foster understanding of future accident scenarios in order to equip highly automated vehicles with new, advanced occupant protection systems
Efficiently tackle simulation of Out of Position situations to pass regulations right the first time

**Highlights**
Joint collaboration on safety simulation in order to efficiently support the development of occupant safety standards
Optimize airbag folding patterns with reduced number of tests

**Key Performance Indicator**
Validate folding variations overnight instead of one week
CUSTOMER SUCCESS

Toyoda Gosei

Cutting lead times in half with virtual prototyping

Highlights
Use ESI Virtual Performance Solution’s airbag module for airbag folding and sewing

Key Performance Indicator
Accuracy and lead time for developing complex Knee Airbag (KnAB) have improved drastically
ACCURATE VIRTUAL PROOF OF WITHSTANDING COLLISIONS SHORTENS DESIGN CYCLES

• Virtually evaluate the most challenging car crash scenarios like small overlap test based on detailed models to understand the behavior of
  • suspension, powertrain, chassis
  • wheels with tire deflation & separation
  • fractured and joined materials
CUSTOMER SUCCESS

Gazelle Tech

Unleash Innovation for New Vehicle Technology and Validate Business Models Early

**Highlights**

Validate the performance of innovative composite vehicle virtually even before the first real prototype is manufactured

**Key Performance Indicator**

1/2 of the typical weight
Reduced energy consumption by 40%
Reduce design iterations to 1 week instead of 5 months
Ensure **Drivability & Durability**

**TIME TO GET REAL: ALL-NEW TECHNOLOGY REQUIRES ALL-NEW TESTING**

- Simulation reigns supreme in reducing model preparation time by 50%
- Evaluate realistic situations and environments and accurately predict operating conditions
CUSTOMER SUCCESS

Honda Motor

Reduce Trial and Development Time Thanks to the Accuracy of Water Impact Simulation Testing

Highlights

Using ESI’s Virtual Performance Solution for water impact simulation

Key Performance Indicator

Ability to run unlimited tests that yielded important results on strength, durability, deformation, fluid flow and intrusion

Image courtesy of Honda Motor
“Thanks to ESI [...] we succeeded in developing one of our new vehicles, achieving good physical tests right the first time, allowing us to earn the whole five stars on the Euro NCAP safety test, following its stricter protocol launched in 2018.”

OLIVIER COLMARD RENAULT
Autonomous Driving Design for Safe & Reliable Vehicles

FOSTER THE UNDERSTANDING OF FUTURE ACCIDENT SCENARIOS

• Equip highly automated vehicles with new, advanced occupant protection systems
• Develop & virtually test radar, camera and LIDAR systems
• physics-based sensor models pave the road for pre-certification of highly automated vehicles
RESEARCH STORY

**Osccar**

Develop a novel, simulation-based approach to safeguard occupants

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**Highlights**

Determine future accident scenarios
Develop advanced occupant protection principles
Assess new safety systems in future vehicles with human body models

**Key Performance Indicator**

Develop robust, efficient crash simulation tools for integrated assessment and overall impact demonstration with standardized virtual testing
Evolve Towards Smart Operator 4.0

Topics
- Product integration validation
- Operator reachability
- Assembly process validation
- Service process validation
Human Centric Product and Process Validation

- Immersive virtual environment to evaluate interactions between people & resources in the processes
- True-to-life human interactions with products and resources in intended use or operation, including wiring & cabling
- Experiential discovery and validation of assembly & maintenance procedures
- First person VR experience with integrated real-time worker ergonomics assessment
Human-Centric Product Integration Validation

EXPERIENCE YOUR PRODUCT IN FULL SIZE AND COLLABORATE WITH STAKEHOLDERS CO-LOCATED OR REMOTE

- In early design stages through the eyes of the operators
- Discover, define, refine, and share product and process requirements
- Create synchronous or persistent experiences
Integrate and build your next vehicle 100% as planned and achieve solid ROI after 8 months. We did this with FCA.
Operator Reachability, Visibility, Accessibility

KEEP AN EYE ON WORKER ERGONOMICS AND TOOLING REQUIREMENTS

• Experience, validate and communicate the impact of production requirements & service procedures without construction of physical prototypes
Working in an immersive virtual reality environment [...] enhances our understanding of complex manufacturing equipment and exposes potential issues, which can be corrected while still in the design stage.

BRAD PRICE

NEXTEER AUTOMOTIVE
Human-Centric Assembly Process Validation

ENSURE SAFE AND PRODUCTIVE PRODUCT ASSEMBLY LINE OPERATIONS AND PRODUCTION ENVIRONMENTS

- Validate assembly processes & cell/line layout
- Identify safe procedures for human operators
- 1st person experiences validated for broad populations—3rd person digital human models
Human-Centric Service Process Validation

ENSURE SAFE AND PRODUCTIVE SERVICE OPERATIONS AND MAINTAIN ZERO DOWNTIME

• Validate service & maintenance procedures
• Conduct ergonomics assessments from first person perspective and validate across wide populations
• Collaborate in experiential serviceability and maintenance process reviews
Watch our on-demand webinars and get concrete, actionable insights from ESI’s experts for Virtual Prototyping in the automotive industry

www.esi-group.com/innovating-the-future-of-mobility