RESEARCH CENTRE FOR THE INDUSTRY

FLANDERS MAKE
DRIVING INNOVATION IN MANUFACTURING

Program pitching day 07-02-2024 Leuven

Park Inn by Radisson Leuven, Martelarenlaan 36, 3010 Leuven (near Leuven Station)

9:30 Welcome coffee

10:00 Plenary session: introduction to our new project idea pitches

10:20 **Project idea pitches** – **session 1**

11:20 Coffee break

11:35 **Project idea pitches** – **session 2**

12:35 Lunch

13:35 Plenary session: guest speaker

14:35 **Project idea pitches** – **session 3**

15:35 Coffee break

15:55 **Project idea pitches** – **session 4**

17:15 Reception

Project ideas sessions

	ERASMUS 1 Production	ERASMUS 2 Sustainability	ERASMUS 3 Working vehicles
	Adaptive and Smart Assembly Systems and Cells **&** **Production Employee 4.0**	**Smart Sustainable Drivetrains** **&** **Sustainable End-to-End Design-Operation**	**Working Vehicles**
10:20	RObotic assembly of DEformable Objects RODEO IRVA	Development & vALidation Of a High-torque-dense Actuator ALOHA_SBO	Automati**CA**lly gene**R**a**T**e and evaluate simulations for validati**O**n of aut**O**nomous fu**N**ctions CARTOON_IRVA
10:40	Efficient Workflow from CAD to Robotic Welding of Small Batches ROBOWELD_IRVA	Evaluation and validation of inline oil monitoring EVOLINE_IRVA	COordinated Motion Interoperability and CompoSability Comics_IRVA
11:00	Coordinated Robot Control for Shared Pick and Place task ROBOSYNC_IRVA **Duo pitch with company**	Pro-active failure prediction & prevention in journal bearings JOURN4LIFE	Interoperability of multi-vendors AMRs INTROMAR_IRVA
11:35	*A*lignment and *L*arge-area tracking for *A*ugmented *R*eality content with *M*inimal *M*arkers ALARMM_SBO	From an organic set of product variants towards a Re-X ready product family OrganiX_IRVA	Scalable Heterogeneous Multiple AMR path planning MultiPaths_IRVA
11.55	Automated Kitting Solutions AKS_IRVA	Value creating circular and sustainable ecosystems CircECOS_SBO	Versatile and Intelligent Techniques for Achieving Optimal and Robust motion scheduling VITAL_IRVA
12:15	Virtual Assembly Replicas for the automated discovery o Factory Improvements VAR4Factory SBO		Automatic Generation of a Warehouse Digital Twin WarehouseDT_IRVA

Project ideas sessions

	ERASMUS 1 Production	ERASMUS 2 Product-production	ERASMUS 3 Motion products
	Production Employee 4.0 **&** **Digitized Production enabling End-to-End Design-Operation**	**Product-Production End-to-End Design-Operation**	**Performance Motion** **&** **Digitized Products enabling End-to-End Design-Operation**
14:35	Enhanced reintegration of workers with physical trauma: a comprehensive assessment framework Heart_IRVA -**Duo pitch with company**	Automated Assembly Sequence Planning Tool Auto-ASP-Tool_IRVA	Demand Driven Control DeDric_IRVA
14:55	Agile Personnel Scheduling in Production Volatile Environments AGIPROVE_IRVA	Product Additions Evaluation System Paves_IRVA	Foundational AI for Forecasting FAIF_IRVA
15:15	Joint Optimization of Electricity Utilities and Daily Production Schedule UTILERGY_IRVA	Reliable product design with uncertainty RelProDes_IRVA	EXtracting KNOwledge for Product Development Engineers EXKNOP_IRVA
15:55	Hidden Trend Analysis for Loss Identification HiTALIc_IRVA	Digital twins supporting process optimization **Duo pitch with company**	**Beh**aviour **A**nomaly Obser**ve**d BehAve_IRVA
16:15	Machine learning for maintanance planning and Spare PARTs mANagement SPARTAN IRVA	Knowledge-based generative design KnoGeDs_SBO	Integrated Testing Analysis and Management Interface ITAMI_IRVA
16:35	Cost-sensitive learning in production for predictive maintenance COSTLEAP_IRVA	Discrete production process optimazation_IRVA **Duo pitch with company**	Using virtualization to allow Microcontroller Units to run non-safety-critical and safety-critical software in full separation. MCUWall_IRVA
16:55	Low-effort defect detection in continuous manufacturing processes RETINA_IRVA	Efficiency improvement in Engineering to Order projects with the use of Knowledge Graph KG-EtO_IRVA **Duo pitch with company**	Microservices for Microcontrollers: Allow for easily updating parts of the microcontroller software by deploying a loosely coupled software architecture on microcontrollers MicroS4MicroC_IRVA
17:15			Transformer based framework for integrating and interpreting multiscale, multirate and multimodal data in mechatronic systems MULTISCALE_SBO

ERASMUS 1 Production

Research Track: Adaptive and Smart Assembly Systems and Cells, Production Employee 4.0 and Digitized Production enabling End-to-End Design-Operation

10:20 **RObotic assembly of DEformable Objects** RODEO IRVA

Flexible parts play a crucial role in many production processes. Think of cables, thin metal sheets, plastic coverings and soft foams. The use of flexible tools is often necessary, making production processes complex.

Although challenging from a technical point of view, this flexibility can actually be the key to developing intelligent tooling solutions and effectively planning and controlling the production process. An example of this kind of solution could be the deployment of robots in the production line.

However, despite advances in sensing technologies, computer performance and information technologies, as well as the development of physical and mathematical models, the industry still faces difficulties when it comes to automatically assembling products with flexible parts.

The biggest hurdle is that robots still have limited manual dexterity and cognitive capabilities to handle such objects in a repeatable and proficient manner. Current programming environments are mainly designed for programming robots working with rigid objects.
In this project, we explore more advanced automation solutions for automatically assembling products with flexible parts.

The aim of this project is to investigate methods that facilitate the deployment of robotic systems in automated assembly with deformable objects.
Concrete objectives here are:

- Study and model, either explicitly or data-driven, the behaviour of selected classes of deformable objects (in consultation with user group members) such as (1D) line-shaped objects (e.g. cables, wires, pipes, rubber seals...) and/or (2D) sheet-shaped objects (e.g. thin metal sheets, composite sheets, textiles...).
- Development/deployment/integration of required robot technologies: sensing - tooling - process control.
- Research on robot programming methods, including learning demonstration methods to efficiently programme and execute robotic tasks involving deformable objects, e.g. control cabinets or (sub)assemblies.

10:40 **Efficient Workflow from CAD to Robotic Welding of Small Batches** ROBOWELD_IRVA

Welding small batches of the same products with robots can present several challenges. While industrial robots are highly efficient for mass production of identical items, they may face difficulties in adapting to small-batch or variable production scenarios. Some common problems include:

1. **Programming Complexity:** Writing and optimizing robot programs for welding small batches can be time-consuming and complex. Each product variation may require a unique program, and frequent reprogramming can slow down the production process.
2. **Changeover Time:** Switching between different product types or sizes may require manual adjustments to the robot's setup, such as changing end-effectors, fixtures, or welding parameters. This changeover time can reduce overall efficiency, especially in small-batch production.
3. **Lack of Flexibility:** Traditional industrial robots may lack the flexibility needed to handle variations in part geometry, size, or material. This limitation can result in the need for additional manual intervention or reconfiguration, diminishing the advantages of automation
4. **Sensing and Vision challenges:** Robots may struggle with accurately sensing and adapting to variations in part positions, orientations, or surface conditions in small-batch production. Implementing advanced sensing and vision systems can help address these challenges but may add complexity and cost.

5. **Cost of Integration:** Integrating robotic welding systems for small-batch production can be expensive. The initial investment in flexible automation solutions, including robot programming, tooling, and sensing systems, may not be justifiable for small production runs
6. **Quality Control:** Ensuring consistent weld quality in small batches can be challenging. Variations in part geometry or material properties may require frequent adjustments to welding parameters, and the lack of continuous monitoring can lead to quality issues.
7. **Human-Robot Collaboration:** In small-batch scenarios, there may be a need for close collaboration between human workers and robots. Ensuring safe and efficient collaboration, along with proper training for human workers, is crucial to maximize productivity.
8. **Maintenance and Downtime:** Robots require regular maintenance, and unexpected downtime can disrupt small-batch production schedules. Predictive maintenance strategies can help mitigate this issue by addressing potential problems before they cause major interruptions.

To overcome these challenges, we want to work on easy-to-program welding robots, with fast changeover times, fixture-free welding, anti-cable wind-up and collision-free path planning.

In this project, we will work on:

- **Welding** (process knowledge): learning welding process parameters/models from operator expertise, optimization of welding parameters and welding order;
- **Robotics** (automation): collision-free path planning including singularity avoidance, cable motion modeling, jig-free multi-robot welding, optimal task and motion planning;
- **Computer vision**: variable workpiece pose estimation, weld process monitoring;
- Close **integration** of the two knowledge domains of welding and robotics

11:00 **Coordinated Robot Control for Shared Pick and Place task** ROBOSYNC_IRVA - **Duo pitch with company**

Conveyor belts equipped with picking robots are found in many companies. The robots collect objects and place them in bins, boxes, bags, etc.; pick out bad products; or sort different products to be transported on one belt. Usually, the first robot in line takes care of the largest load, while the other robots pick the remaining objects.

To efficiently schedule several robots, many companies run into problems. Currently, optimal planning software is available in the market for planning with 1 robot. But getting multiple robots to work together efficiently is a challenge for many companies. This translates into:

1. Energy wastage (robots not used optimally)
2. Expected capacity not being met (too many/too few robots on the line)
3. System builders struggling to predict the relationship between capacity and the number of robots needed in highly variable production lines.

In this project, we work on coordinated task allocation between robots on a conveyor belt. Here, we take into account the belt speed, frequent rescheduling and the impact of our predictions on the optimality of the planner. In case a conveyor belt is not continuously loaded, we make a trade-off analysis. Here, we compare a robust solution (with more than enough robots) or a flexible solution with variable conveyor speed and fewer robots.

The result of the project is a layered control body with planning algorithm and robot control algorithm that optimises task distribution and motion planning online. The robot control software will be integratable with classic pick-and-place robots.

11:35 **A**lignment and **L**arge-area tracking for **A**ugmented **R**eality content with **M**inimal **M**arkers
ALARMM_SBO

For many industrial tasks, the operator can be supported by Augmented Reality (AR) technology in which **digital annotations are precisely aligned atop the physical workspace**. Examples of such industrial tasks include:

- Assembly operations
- Fixing errors that cause production machine stops
- Safety inspection and shopfloor maintenance
- Warehouse management and intra-factory logistics

State-of-Practice AR solutions for these types of tasks exist mostly for confined spatial areas only (e.g., at the level of individual workstations). When scaling up to larger areas (e.g., factory-wide), existing solutions often rely heavily on physical markers for spatial alignment and tracking. However, **the use of markers in large-scale workspaces is inflexible and can be prohibitively expensive**.

In this project we aim to improve the **calibration and alignment of cameras in large-scale augmented reality settings.** Hereby relying as little as possible on **physical markers**.

Current state-of-the-art tracking solutions easily degrade to more than 10cm mismatch in large production areas. Our goal is to achieve AR visualizations that are that can be used factory-wide with **at a precision tolerance of <1 cm**.

Depending on the companies involved in this project, we can integrate the resulting **6DoF tracking software** in various types of AR setups like **Head-Mounted Displays (HMDs)**, mobile and portable **projectors**, and 2D displays (e.g., tablets) that support **AR passthrough**.

11.55 **Automated Kitting Solutions** AKS_IRVA

Many manufacturing companies supply parts to their assembly cells in kits. Kitting is a non-added-value activity, performed by humans to cope with product variability and uncertainty. Kitting results often in high-ergonomic loads for the operator. And the cost decreases the earnings from the automated assembly. Furthermore, automating the kitting is challenging when dealing with high product variability (and small batch sizes).

In this project, we will realize concepts of operation and related system architectures for smart flexible automatic kitting systems which can handle large product variability in an economically viable way.

12:15 **Virtual Assembly Replicas for the automated discovery of Factory Improvements** -VAR4Factory SBO

Creating a digital twin of an assembly environment involves constantly refreshing it with data gathered from the real system. However, manually adding data to these digital models is impractical, demanding substantial time and effort of your skilled workforce.

The solution lies in automating the adaptation of digital models to align with real system data, while detecting its modifications and deviations. This enables reliable predictions of the current and future behaviors on the shop floor.

Cutting-edge practices are beginning to merge data-driven approaches (like mining historical event logs from systems such as ERP/MES) with formal expert knowledge (drawn from master data like BOM/BOL). This combination aims to accelerate the creation, adjustment, and validation of models.

In this project, we seek to apply these real-time simulation models to intricate assembly processes. We aim to automatically uncover and confirm various improvement possibilities by identifying "clear errors" in assembly operations, such as suboptimal layout, unbalanced production lines, scheduling issues, delayed part deliveries, and bottleneck detection. The outcome will be a decision support system that alerts operations or production managers to potential enhancements and estimates their impact on performance.

14:35 **Enhanced reintegration of workers with physical trauma: a comprehensive assessment framework**

Heart_IRVA **Duo pitch with company**

Reintegrating workers with physical trauma presents challenges for the industry, including:

- **Physical Limitations:** Workers may face challenges due to mobility or strength limitations.
- **Work Environment Adaptation:** Modifications are needed in the workplace to accommodate physical disabilities.
- **Skills and Training:** Additional training is essential for adapting to new work processes or technologies.
- **Attitude and Stigma:** Overcoming negative attitudes and fostering an inclusive workplace culture is crucial.
- **Psychosocial Factors:** Addressing psychological challenges such as anxiety or lack of confidence is important.
- **Legal Compliance:** Adhering to legal requirements for workplace accommodations is crucial.
- **Costs and Resources:** Allocating resources for accommodations, rehabilitation, and support services can be challenging
- **Communication and Coordination:** Effective communication between employers, healthcare professionals, and workers is vital.
- **Return-to-Work Programs:** Developing effective return-to-work programs requires careful planning.
- **Accessibility of Information:** Ensuring all information is accessible to workers with disabilities is essential.

A holistic, collaborative approach is needed to overcome these challenges and create a supportive environment for successful worker reintegration.

Empowering individuals to contribute to society through meaningful employment significantly enhances their overall quality of life. **Our project is dedicated to this cause, focusing on the evaluation of workers with physical injuries in a comprehensive manner that goes beyond traditional ergonomic assessments.**

By integrating biomechanical, physiological, and ergonomic evaluations, our goal is to align the capabilities of workers with the specific demands of their jobs. This holistic approach allows for a tailored reintroduction of individuals into the workforce, ensuring a smoother transition.

In collaboration with medical practitioners, our project is developing a framework that caters to both industrial and medical needs. We carefully select metrics from biomechanical, physiological, and ergonomic dimensions to create a comprehensive evaluation system. This system adheres to industry and medical standards, enabling continuous assessments that provide nuanced insights into users' work capabilities.

By combining industrial and medical expertise, our research aims to enhance the precision of reintegration evaluations. Ultimately, our goal is to contribute to the creation of a responsive workplace that supports individuals recovering from physical traumas, fostering an environment where everyone can thrive.

14:55 **Agile Personnel Scheduling in Production Volatile Environments** AGIPROVE_IRVA

Are you grappling with the uncertainties of a production landscape marked by erratic demand and frequent disruptions to schedules? Are you seeking cost-effective strategies to align your production and human resource planning and scheduling across strategic, tactical, and operational levels?

In dynamic production environments, companies face pressing challenges that demand flexible scheduling solutions. Current software packages exacerbate these challenges by offering isolated reasoning at either the strategic, tactical, or operational level. They lack sufficient support for proactive decision-making and fail to accommodate desired agility policies and dynamic scheduling. Additionally, the separation of job planning from resource (personnel) planning results in suboptimal solutions. Finally, there is a noticeable absence of mechanisms for proactive and reactive recovery, as well as decision support.

The industry requires a comprehensive solution to enhance the operational efficiency of flexible job and resource planning and scheduling.

In this project, we will design a decision support planning scheduling engine for agile task/job and personnel planning and scheduling in dynamic and volatile production environments.

We will study the impact of implementing multiple ways of adding flexibility at the strategic, tactical and operational level of decision-making encompassing proactive and reactive (either event-driven, periodically, or hybrid) scheduling (e.g. task swapping) in response to demand fluctuations and schedule disruptions.

The decision support tool will optimally introduce flexibility/agility into resource management Additionally, it will calculate the impact of strategic (e.g. such as skill mix, overtime, annualised hours, overtime, …) and tactical decisions (e.g. capacity and time buffering) on operational outcomes. The analysis will consider the trade-off between agility and economic factors. It will further evaluate/balance personnel satisfaction proxies. The goal is to help companies optimize personnel resources, enhance competitiveness, and streamline operations for resilience and adaptability.

15:15 **Joint Optimization of Electricity Utilities and Daily Production Schedule** UTILERGY_IRVA

Imagine a world in which manufacturing companies do not have to worry about their energy supply. Not only because they have their own renewable energy sources, but more importantly because their entire production system has been designed and is managed to optimally use the available electrical energy. We can achieve this by actively manage your companies' renewables (solar panels, wind turbines) so that they correspond to your daily production schedule's needs.
Basically, we make your energy management 'smart'. We not only look at the demand side (How much power do I need to run X production lines?) but also at the supply side (How much energy am I currently generating?) and subsequently, we make the demand and supply flexible. As a result, your production will become cheaper (lower electricity costs), without sacrificing capacity since your energy consumption is shifted to cheaper time periods.

In this project, we're working on a comprehensive approach to align electricity **supply** (grid, renewables), **storage** (industrial batteries), and **demand** (from production).
By optimizing how we source electricity and plan daily production, we aim to cut costs and enhance flexibility in demand, storage, and supply.
Our goal is to create a daily energy-aware scheduling system that considers production goals, electricity costs, availability of (external) renewables, and energy storage. We'll also factor in predictions from the day-ahead energy market.

15:55 **Hidden Trend Analysis for Loss Identification** HiTALIc_IRVA

With the advent of Industrial Internet of Things (IIoT), companies can now gather extensive data on their production processes. However, many struggle to unlock the full potential of this valuable resource. One promising application is using this data to identify production issues like speed reduction or quality problems and uncover their root causes.

However, these problems are challenging to detect since they often result from multiple factors, manifesting as subtle deviations or anomalies in the data that might be easily overlooked by a data analyst. Another hurdle is ensuring the accuracy of the data: Although IIoT data is generally more reliable than manually entered manufacturing data, errors still exist and can lead to inaccurate conclusions in the analysis.

The goal of this project is to:

- Develop a framework for validating and analyzing Industrial Internet of Things (IIoT) data.
- Explore enriching typical IIoT (time series) data with real-time contextual information for root cause analysis.
- Evaluate the performance of various data validation and cleaning methods used in big data applications for manufacturing (IIoT) data.
- Develop methods to identify hidden trends in contextualized IIoT data leading to production losses (OEE).
- Visualize results in a dynamic dashboard, providing relevant information, events, trends, and issues for the user (data analyst).

16:15 **Machine learning for maintanance planning and Spare PARTs mANagement** SPARTAN_IRVA

Cutting-edge industrial machines produce valuable data that helps assess their wear and tear for effective preventive maintenance planning. Achieving cost-effective maintenance also relies on a well-designed spare parts management strategy. Companies require strategies and smart algorithms to improve their spare parts management and optimize maintenance planning by leveraging degradation data.

Our main goal is to create algorithms that utilize real-time data for enhanced management of spare parts and maintenance. These algorithms serve as the analytical backbone for Original Equipment Manufacturers' (OEMs) service control towers, aiding in their processes for maintenance and spare parts decision making.The following breakthroughs are envisaged:

16:35 **Cost-sensitive learning in production for predictive maintenance** COSTLEAP_IRVA

Do you want to decrease your total cost of production maintenance?

Companies maintain their machinery in different ways. This can be in a reactive, preventive or condition-based manner. In the past, much attention was also paid to predicting the remaining useful life (RUL) of a machine. For this, it was important to understand the physics of your machines to the core.

Whichever way you go about it, the goal of a good maintenance strategy remains the same: to ensure continuity and thus reduce operating costs - after all, machine/production downtime automatically means high costs. This can be achieved in 2 ways:

- In a 'down-to-earth' way using historical, operational information;
- In a cost-conscious way.

In this project, we look for a smart way of maintenance, linking human expertise, machine data and machine learning.

Here, we focus on the following sectors/applications:

- Manufacturing companies with CNC machines, overhead cranes, cranes, compressors, ... who want to save costs;
- Companies deploying a fleet of assets (e.g. charging stations, wind turbines, ...) and responsible for maintenance;
- Suppliers of consumables such as machine tools, rotating equipment;
- Technology suppliers to support maintenance strategies.

In this project we use readily available operational data (e.g. amount of active hours, product volume, historic maintenance interventions, quality report …) and combine it with cost models to account for cost of too early tool replacement, risk of downtime, etc..

The goal is to define a **machine learning-based tool supported by expert knowledge** (and potentially more detailed condition monitoring machine data) **that lowers the costs of your maintenance programme.**

16:55 **Low-effort defect detection in continuous manufacturing processes** RETINA_IRVA

In high-speed production lines, spotting defects or quality issues early on is crucial to avoid unnecessary waste. Therefore, you'll need a quality control system that can quickly make real-time decisions about quality and alert you if there's a problem. It would be even better if this system could gather detailed information about the defective parts, saving time and money on quality control.

Most current solutions focus on one-step processes that involve a lot of data collection, storage, and labeling—often done by experts. Unfortunately, these systems are (too) slow for fast-paced production processes.

So, with this project, we are working on a quality system that can instantly detect defects in a high-speed production process and allows us to improve the quality without a lot of manual labeling.

The goal of this project is to develop a two-stage defect detection system that minimizes labelling effort and avoids complex data storage and management.

- The first part of our system works on the production line. Here, we use a smart detection system to differentiate normal and defective samples without the need for data labelling.
- The second part works off line. Here, we improve the defect detection by learning from the filtered data. The system focuses on understanding the type of defect and its location.

This two-step process allows for quick real-time decisions about product quality and further (offline) defect analysis to optimize the production process.

Our system (called RETINA) is edge-based and can be deployed on an embedded device, speeding up the process and eliminating the need for storing data in the cloud. Plus, it connects directly to the machines or process, giving us only the most important quality information.

ERASMUS 2

Research Track: Smart Sustainable Drivetrains Sustainable

10:20 **Development & vALidation Of a High-torque-dense Actuator** ALOHA_SBO

The demand for robust, high-power actuators in industries such as off-road machinery, material handling, wind turbines, and aeronautics continues to grow. Companies like Dana, Bucher and Cascade Drives are leading the way in developing actuators that offer superior torque densities, increased efficiency, reduced noise levels, and minimized fluid leakage risks.

As industries strive for higher torque densities and improved efficiencies, particularly in applications with flexible duty cycles, there is a notable shift towards the electrification of hydraulic actuators. However, the potential of electric drives to deliver high-torque actuators is hindered by the limitations of high-ratio gearboxes, which are necessary to achieve superior torque densities.

In the realm of off-road vehicles and agricultural machinery, companies exploring the electrification of their products prefer compact, power-dense, and highly efficient electric motors borrowed from transport applications. These motors operate at high speeds, while the vehicles and machines in question require low wheel speeds. Traditional transmission designs with a 3-step reduction can result in higher mass, larger volume, and integration challenges, further complicating the pursuit of electrification in these industries.

The primary goal of this research project is to develop an advanced electric actuation system with a power rating exceeding 50 kilowatts, characterized by high torque density.
This system will seamlessly integrate in already available power-dense and efficient electric motor technology with a novel compact, Wolfrom-based high-ratio gearbox that can achieve elevated efficiency while providing substantial gear ratios. The overarching aim is to augment and assess the potential of electric actuators as high-power devices across diverse industries and applications in terms of torque density, efficiency, versatility, compactness, cost-effectiveness, noise, and scalability.

10:40 **Evaluation and validation of inline oil monitoring** EVOLINE_IRVA

Companies need reliable and strong oil condition monitoring tools for maintaining the well-being of their gearboxes and hydraulic systems, and extend the lifespan of components by minimizing oil change intervals. There are, however 3 main challenges in this regard:

- Despite the extensive theoretical possibilities in this field, the primary challenge stems from the **difficult access to real-time inline information**, specifically concerning viscosity and wear debris composition.
- Furthermore, it's **challenging to understand** how **different sensor technologies** compare in terms of reliability and robustness.
- Additionally, it remains uncertain whether and how **oil monitoring can offer insights into the degradation of components** and, consequently, their lifespan.

In this project, we will investigate and validate inline oil monitoring, including both analysis of the oil itself (with a focus on viscosity and water content) and of the wear particles in the oil (mainly their composition and size).

We'll set up a test rig, integrating various sensors under controlled conditions for thorough testing. Using design experiments, we'll create assessment metrics for reliability, sensitivity, accuracy, and robustness. We'll check the feasibility of connecting oil monitoring data with other types (like direct vision or vibration) for estimating component/gearbox remaining useful lifetime. These insights will help company users to compare and select the best sensors for their specific needs.

In addition, monitoring oil condition and wear debris will provide information on oil quality, optimizing change intervals and possible links to lifetime estimations.

11:00 **Pro-active failure prediction & prevention in journal bearings** JOURN4LIFE

In current drivetrain applications, companies face the issue that they cannot prevent a failure, but rather can detect a failure & predict the remaining lifetime. This remaining lifetime is typically very short in e.g. journal bearings and can lead to unwanted machine failure and or high service interval costs. Therefore, we want to detect and prevent failures before they occur using novel sensors and active prevention measures in industrial applications using journal bearings.

Journal bearings, commonly used in industrial machinery under high loads, low speeds, or harsh conditions, pose challenges. Their failure is often catastrophic with no early signs, and conventional methods signal failures when it's too late, resulting in substantial economic losses.

The industry therefore needs:

1. Predictive methods for early failure detection.
2. Prevention methodologies to extend machine lifetime and reduce machine costs.

However, the industry faces several challenges:

1. There are no predictive methods and sensors available for detecting and understanding the early failure mechanisms inside machines.
2. No preventive methods can be taken to mitigate failures if they are not detected.

Addressing these needs and barriers is vital for proactive maintenance and cost-effective operations in industries relying on journal bearings.

The goals of this project are:

1. To investigate and understand the failure mechanisms of journal bearings;
2. To establish how to sense these failures;
3. To implement failure mitigation/prevention techniques.

Research Track: Sustainable End-to-End Design-Operation

11:35 **From an organic set of product variants towards a Re-X ready product family** OrganiX_IRVA

Do you have many product variants and you want to organize them better to be more future proof? For the front-runners, you want to assess if you are ready to make the step towards re-X strategies?
Then this project will help you to organize your product family in a semi-automated way, and it will develop strategies to assess and improve your family for re-X strategies.

The goal of the project is to:

- Semi-automate the organization of a(n organic product) data base, by automatic interpretation and clustering analysis on CAD files.
- Develop methods and tooling to assess and improve the family for Re-X strategies

11.55 **Value creating circular and sustainable ecosystems** CircECOS_SBO

In order to achieve sustainable products and services, companies need to collaborate with various stakeholders. However how to set up these ecosystems, how to distribute costs and values, and how to decide which data can be shared is an open challenge.

In this project, we will start from a set of generic use cases to set up frameworks for requirements for DPP-based data sharing and value distributions across the involved stakeholders.

The focus lies on creating ecosystems, across companies, to increase sustainability of produces throughout their lifecycle leveraging on the various R-strategies.

Research Track: Product-Production End-to-End Design-Operation

14:35

Automated Assembly Sequence Planning Tool Auto-ASP-Tool_IRVA

Defining a cost and time efficient assembly sequence for a new product is a time consuming and error prone task that requires multiple try-outs and physical prototypes.

In this project we will develop a prototype tool that semi-automatically generates and evaluates an assembly sequences for a product starting from a virtual product model (augmented CAD) and production model (augmented flow-graph).

14:55

Product Additions Evaluation System Paves_IRVA

The challenge in estimating the financial impact of new product variants lies in the often overlooked indirect costs, R&D expenses, and project-related costs. Current practices typically focus on direct costs, neglecting a holistic view.

Companies are in need of a comprehensive cost model that considers these nuances, incorporating factors like component commonality for economies of scale. Furthermore, the inclusion of a benefits model that captures both direct gains and indirect effects (such as potential cannibalization of existing products) is essential to create a comprehensive business case. Interactive scenario testing under various assumptions is vital. Transparency is key—users should comprehend the model components, avoiding a black-box scenario.

Our project addresses these industry needs, offering a nuanced decision support tool for strategic product expansion.

In this project, we're developing a powerful decision support tool for companies exploring the addition or removal of product variants. Our framework includes:

- **An integrated holistic cost accounting model:** This model considers both direct and indirect costs and benefits, aiding in the creation of a comprehensive financial business case.
- **A feature modeling representation of product variants:** Enhancing user understanding through a visual representation of model components, which eases flexible extensions and manipulation.
- **A knowledge base framework:** This enriches the feature model with context information and supports interactive querying.

Together, these components empower users to conduct user-friendly, interactive simulations, facilitating informed and strategic decisions in product portfolio management.

15:15

Reliable product design with uncertainty RelProDes_IRVA

Are you confronted with uncertainty and/or variability in your numerical models? This project offers a solution for robust and reliable design.
As design calculations become more complex, an increasing number of parameters need specification, many of which are unknown during the design phase. Additionally, manufacturing processes introduce variability in the final product. Ideally, analysis tools should incorporate these uncertainties to inform design decisions, such as assessing the reliability or robustness of the intended product performance.
However, current uncertainty quantification techniques, while advanced, face challenges in their practical application to large, complex, industrial-scale models. Efficient implementation, especially for spatially varying parameters, poses computational challenges that often limit their use in modern design tools.

This project is all about creating design tools that factor in uncertainties in large-scale finite element problems, pushing the boundaries of modern uncertainty quantification approaches.

Our main focus is on developing a numerically efficient framework that strikes a balance between realism and computational efficiency. We're putting a spotlight on the use of cutting-edge surrogate

models with active learning, specifically designed to handle uncertainty propagation. Spatial uncertainty, which involves local and global variations due to factors like manufacturing or loading, is a key consideration
.
Our aim is to provide tailored solutions for situations with limited data availability, enabling the incorporation of parameter dependencies and correlations. The envisioned design procedures are geared towards producing robust and reliable products, paving the way for a wider adoption of advanced uncertainty quantification tools in the design process.

15:55 **Digital twins supporting process optimization - Duo pitch with company**

Configuring the settings for a new product within complex mechatronic systems involves optimizing many hundreds, sometimes thousands, of parameters. Currently, this is predominantly a manual process heavily dependent on the experience of operators and process engineers. Given the multitude of settings, there is a clear need for a solution that provides visualizations and automatic analysis of the effects of these settings on the feasibility of motion and product quality. Such a tool would significantly enhance the efficiency and accuracy of the optimization process in complex mechatronic manufacturing systems.

In this project, we will develop a tool for early detection of potential production problems, conflicts, and quality issues while allowing for a gradual, iterative optimization of the production output.

16:15 **Knowledge-based generative design** KnoGeDs_SBO

Creating modern product designs is constrained by a designer's capacity to encompass the complete complexity of potential influences, encompassing factors such as cost, manufacturability, and usability.

In this project, we're using smart AI to automatically create augmented Computer-Aided Designs (CAD). These improved CAD helps us apply the latest design and optimization techniques.

16:35 **Discrete production process optimization - Duo pitch with company**

Numerous production processes involve a sequence of distinct physical transformations. While each transformation is constrained by the capabilities of the employed mechatronic system, certain processes allow a degree of freedom in selecting each transformation.
The current challenge lies in the manual nature of designing an optimal sequence of transformations that considers all manufacturing limitations. This process heavily relies on experienced engineers, highlighting the need for more automated and efficient solutions in the design of these intricate manufacturing processes.

The goal of this project is **to design a tool that supports, and possibly automates, the design process,** while taken machine capabilities and limitations into account.

16:55 **Efficiency improvement in Engineering to Order projects with the use of Knowledge Graph**
KG-EtO_IRVA - **Duo pitch with company**

In the various phases of engineering complex systems, especially in engineering-to-order projects, data such as specifications, data sheets, reports, models, drawings, supplier information, and quotes are collected in separate systems like PLM, CRM, ERP, etc.

While an internal process model, often based on knowledge graph technology, effectively manages system data and workflows, handling third-party documentation remains an enormous challenge.

The information related to third-party products is typically stored in traditional documents like offers, specifications, invoices, RFIs, making it a time-consuming and error-prone task to manage and trace such data. The ideal solution would involve the (semi)-automatic integration of third-party documentations into internal engineering processes and workflows. Achieving this could significantly enhance the efficiency and quality of managing the lifecycle of complex systems.

This project aims to:

- Enhance engineering support for complex Engineer To Order Projects during the entire lifecycle ;
- Increase engineering quality by standardization of workflows for (3rd parties) document registration, verification and validation processes;
- Better support in knowledge handover to new project stakeholders.

ERASMUS 3

Research Track: Working vehicles

10:20 **AutomatiCAlly geneRaTe and evaluate simulations for validatiOn of autOnomous fuNctions**
CARTOON_IRVA

There is always a need to simulate your autonomous functions (such as perception and control) of your autonomous vehicles before real-life deployment. The scenarios should be automatically generated and the evaluation needs to be done automatically as well such that the engineer does not lose much time on this. The scenarios should be generated such that it covers the operational design domain, which poses the following research questions:

- How detailed should the simulation be?
- How to determine the coverage?
- How to smartly chose your next scenario based on the outcome of previous results?

The goal is to provide a framework for an **automatic scenario generation and fast evaluation for autonomous vehicles to validate your perception or control systems in simulation**.

To further improve the time-efficiency of this validation, we aim to include **next generation Design-of-experiments**: use knowledge from previous test to detail next test case based on AI. We aim to apply this framework to two simulation tools.

10:40 **COordinated Motion Interoperability and CompoSability** Comics_IRVA

Get ready for the future of work automation! Soon, your warehouse or factory will use advanced automation systems from different suppliers. Imagine these systems working together seamlessly. Riding from one to the next assembly station, handing over assembly parts to the following machine. Sounds great, doesn't it? However, without an orchestrator that coordinates these multi-supplier/multi-type collaborations, this will be very hard to achieve.

In this project we will help you to:

1. Understand the current interoperability standards and what add-ons you need for complex tasks.
2. How to add new automation solutions to your existing setup.
3.

This will result in:

- For regular users: More flexibility for your team and new features, saving you money.
- For software developers: Ensure composability (seamless operations with systems from other suppliers) in your software as additional selling points.
- For autonomous vehicle/drone integrators: Add new solutions faster and better than before.

In scenarios involving the coordinated operation of diverse vehicles or robots, significant technological challenges persist. A major barrier is the extensive orchestration needed for both task specification and execution, with no existing standards in place.

Our project is dedicated to formalizing orchestration patterns that accommodate a wide range of vehicles, robots, and their associated functions. The primary objective is to ensure scalability and composability, allowing for the seamless addition of extra vehicles or robots.

The formalization process will undergo validation through real-world use cases, incorporating elements such as control, situational awareness, communication technology, and mechatronics design. It's important to note that optimizing these technologies specifically for flock systems is out of the scope of this project.

11:00 **Interoperability of multi-vendors AMRs** INTROMAR_IRVA

As companies integrate diverse Autonomous Mobile Robots (AMRs) and other resources (such as conveyor belts) into their warehouses, their limited interaction hampers efficiency (e.g., AMRs see others as obstacles). To enhance scalability and efficiency, seamless data exchange between AMRs, resources, and the Warehouse Management System (WMS) is crucial.

End-users are cautious about vendor lock-in when purchasing new AMRs. They seek assurance that their chosen AMRs, existing resources, and WMS are compatible with various vendors, ensuring future adaptability.

In this project we work on an interoperability test toolbox for AMRs from different suppliers.

The goals of this project are:

1. Improve the current interoperable middleware solution (open RMF) by introducing company specific resources;
2. Improve the current use of the standard (VDA5050) on interoperable data exchange by:
    1. adding map information
    2. link to interoperable middleware (open RMF)
3. Create an **interoperability test toolbox** to advise end-users **to avoid vendor lock-in** when buying (new) AMRs.

11:35 **Scalable Heterogeneous Multiple AMR path planning** MultiPaths_IRVA

More and more Autonomous Mobile Robots (AMRs) are added to warehouses. This requires scalable and time-optimal multi-AMR path planning. Current state-of-practise solutions are often not scalable nor time-optimal, which results in long waiting times.

Within this project, we will provide a scalable solution for multi-AMR path planning for heterogeneous fleets which aims to improve:

1. Time-optimality (no long waiting times on other AMRs / conflicts)
2. Flexibility w.r.t. task allocation
3. Efficiency in terms of energy-consumption

11.55 **Versatile and Intelligent Techniques for Achieving Optimal and Robust motion scheduling** VITAL_IRVA

This project originates from a prior research project that addressed vineyard coverage challenges. This previous project focused on:

1. Determining the optimal row sequence for comprehensive vineyard coverage.
2. Efficient cost calculation and turn feasibility.
3. Utilizing a discrete optimizer with a cost "map" for optimal scheduling.

With this project, we aim to extend the reach of optimal sequencing and motion planning, responding to the widespread demand for versatile and intelligent techniques. We concentrate on applications such as agriculture (indoor/outdoor), harbor container handling, "Collect and Go" systems in supermarkets, warehouses, distribution centers, product transport, complex construction sites, including dredging with multiple ships, and more.

This project focusses on **efficient, robust and optimal planning of multiple motion tasks** for one or several agents (working vehicles).

- **Efficiency** means that the planning must be computationally efficient (almost real-time). For that, the cost of individual tasks is calculated in advance. We will research different (existing) optimization tools to implement (a) suitable discrete optimizer(s).
- **Robust** means that fast replanning will be possible in case of unexpected events/obstacles and to manage interactions and congestions.
-

This planner can be used for autonomous motion systems or as a driver assistance tool with the possibility to provide multiple solutions/suggestions for the operator.

12:15 **Automatic Generation of a Warehouse Digital Twin** WarehouseDT_IRVA

Tackling the industrial challenge of creating and maintaining a **digital twin for warehouses** demands time and resources. Integrating it seamlessly with product data, warehouse management, fleet systems, and additional infrastructure presents complexities. The precision required for an accurate visualization adds to the challenge, with a steep learning curve. Exploring this challenge prompts the question: What other applications can be empowered or supported through the use of such a digital twin in an industrial context?

In this project, we aim to develop a streamlined process. It involves generating a semantic map of a warehouse, enhancing object information using a knowledge base infused with company-specific domain knowledge. This process results in the creation of a digital twin with versatile applications, including but not limited to:

- Automatically build an accurate simulation of the environment from data gathered by a robot.
- Link the warehouse content and the simulation environment to a warehouse management system (WMS).
- Schedule fleets of AMRs based on requests from the WMS
- Reason about/abstract locations of products/machines for simplifying human-robot interaction/programming
- Optimize the product placement and (work)flows in the warehouse

Research Track: Performance Motion

14:35 **Demand Driven Control** DeDric_IRVA

Many industrial systems rely on conservative control setpoints that generally perform adequately despite variations in demand, load, disturbances, and other factors. For instance, in water treatment, fixed power levels are often employed, even though they may be excessive during lower-than-usual demand, resulting in energy wastage.
This trend is observed in various systems, including cooling/heating systems, process control, smart grids, HVAC systems, and more. It typically applies to systems where running at a consistently high power level is unnecessary due to fluctuations in demand or other variables.

Our project focuses on crafting demand-driven control methods, optimizing the scheduling of unit usage and power levels. Unlike conservative or fixed setpoints, these methods leverage predictions of variations in demand, load, disturbances, inflow, and energy prices. Additionally, they make use of existing storage or buffer capacities within the system.

The outcome is a **reduction in energy consumption and/or extended machine lifespan,** achieved by running at more favorable levels and minimizing on/off switches.

14:55 **Foundational AI for Forecasting** FAIF_IRVA

Forecasting empowers industrial energy stakeholders to proactively plan for future energy demands, optimizing production, ensuring ample supply, and simultaneously reducing costs and energy consumption.

For industrial equipment users and manufacturers, forecasting serves as a valuable tool to identify anomalies in equipment performance or trigger preventive maintenance. By comparing predicted future behaviors with real-time data, potential issues can be addressed proactively.

Yet, accurate forecasting is not a one-size-fits-all solution. Common challenges include:

1. Data Quality: Noisy or intermittent data can pose challenges.
2. Data Quantity: Limited data availability for development.
3. Model Selection: Choosing the most effective model is complex, given the diverse strengths, weaknesses, assumptions, and requirements of different models.

This undertaking demands substantial time and effort from a company's engineering team or may even require external assistance.

The goal of this project is to create a powerful software library for precise forecasting across diverse scenarios. The library will use foundational AI models. These versatile algorithms (like ChatGPT - known for its natural language capabilities) will be applied to analyze data from various sensors. This approach not only streamlines the forecasting process but also minimizes the time and effort typically invested in trial-and-error cycles by engineers. The software library takes charge of addressing both data quality and quantity challenges, automatically selecting the optimal AI model for each situation. Notably, it operates seamlessly online, eliminating the need for specialized AI hardware.

Research Track: Digitized Products enabling End-to-End Design-Operation

15:15 **EXtracting KNOwledge for Product Development Engineers** EXKNOP_IRVA

We recognized a crucial need in companies actively involved in the functional design of mechatronic products – the need for better capturing and sharing of design knowledge.

Designing and developing mechatronic products is a complex process. Product development and design engineers navigate various data sources, utilize diverse methods such as simulations and experiments, and make critical decisions. However, the documentation of this intricate product development process is currently constrained, hindering companies from efficiently extracting knowledge from previous designs to support new product development cycles.

This project aims to address this challenge by enhancing the capture and organization of knowledge from both past and ongoing designs. This improvement will significantly benefit product development engineers, offering valuable insights and streamlining their decision-making processes. By overcoming these limitations in knowledge extraction and sharing, our project not only optimizes current practices but also empowers engineers with a more informed and efficient approach to product development. Participate in ths project and experience how we're revolutionizing knowledge sharing in mechatronic product design!

Our primary goal is to develop an integrated framework, equipped with industrially relevant tools, to capture and share design knowledge seamlessly during the product development and design of functional mechatronic products.

Within this comprehensive framework for New Product Development (NPD) processes, we are building a sophisticated model of the design process. This involves a combination of process discovery techniques, including traditional methods like observations, interviews, and workshops for employee involvement, alongside automatic process discovery (process mining) for structured data and Natural Language Processing for unstructured data.
Moreover, our research is dedicated to establishing a Formal Product Model Ontology. We achieve this by reusing existing ontologies and employing ontology engineering methodology to accommodate diverse design iterations. The ultimate objective is to capture the execution of the design process and establish a knowledge graph/object-centered event log that links it with design decisions and product model instantiation.

This innovative framework is designed to learn from the captured knowledge, actively supporting product development engineers and designers throughout the design process. From providing static support, such as pointing to relevant documents, to dynamic support, such as suggesting the next step in the design process, our aim is to enhance and streamline the entire product development journey.

15:55 **Behavioural Anomaly Observed:** BehAve_IRVA

Manufacturers of cyber-physical systems are often unsure of the behaviour of their system once it is installed at the customer's premises. Once their customers complain about unwanted behaviour, it often takes a lot of effort to get information about this behaviour via logging or tracing. But even then, it is still not easy to reproduce and analyse this erroneous behaviour.

Therefore, manufacturers need more efficient ways to detect anomalies in their systems, and preferably before their customers do. Based on results of a previous research project, we want to apply the possibilities of Complex Event Processing in a tracing analysis pipeline to detect the behaviour of the system based on defined patterns. These patterns can be created manually in a test phase of the development of the system or generated by mining existing traces for behavioural patterns.

The goal of the project is to understand an application of Complex Event Processing for behavioural pattern matching and to show the use of automatic learning of behavioural patterns.

16:15 **Integrated Testing Analysis and Management Interface** ITAMI_IRVA

In the dynamic landscape of designing sophisticated systems, an industry-wide challenge has surfaced: the need for a more efficient and organized testing process. The current struggle lies in the scattered nature of information related to system tests—requirements, bug reports, and test results are dispersed across various sources. This fragmentation hampers the ability to attain a unified and comprehensive overview of the overall test status.

Companies actively engaged in system testing encounter specific challenges:

1. Insightful Overview: Grasping a complete understanding of the overall test status remains a significant hurdle.
2. Decision Complexity: Determining which tests to skip and which to re-execute proves to be a complex decision-making process.
3. Analysis Hurdles: Evaluating test quality across different product versions and pinpointing gaps in requirements coverage presents notable challenges.

These challenges underscore the need for innovative solutions and frameworks. We are in search of tools that can seamlessly consolidate and present information, providing high-level insights and advanced analysis capabilities. Companies that tackle these testing complexities will not only elevate their operational efficiency but also usher in a new era of informed and strategic decision-making in system testing processes.
Based on previous research results, we will develop a generic interface on which companies can connect their data sources. The project will investigate best practices on data restructuring to enable the creation of front-end dashboards providing insights in the overall test status.
To assist in the decision support, we will investigate the use of version control algorithms on the Knowledge Graph. Traceability algorithms and Machine Learning algorithms are considered to support our analysis.

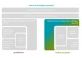
16:35 **Using virtualization to allow Microcontroller Units to run non-safety-critical and safety-critical software in full separation.**MCUWall_IRVA

Are you involved in product design within industries that demand strict adherence to functional safety regulations, such as automotive, turbines, or trains? Do you find the separation of safety-critical and non-safety-critical control logic challenging due to hardware costs? Are you looking for a solution that enables easier system updates without the hassle of regulatory audits for safety-critical components?

In an era of constant industrial evolution, optimizing resources and development costs is a perpetual goal. The industry seeks ways to streamline product development by leveraging more generic platforms. The challenge lies in finding methods to transition custom hardware for safety-critical systems into software running on generic MCUs. This shift not only reduces resource costs by eliminating the need for specific hardware but also streamlines the development process by eliminating the necessity to create and test custom hardware. Join us in tackling this industrial challenge to enhance efficiency and innovation in product development.

With this project we will show the possibility of running non-safety-critical software alongside safety-critical software on one virtual microcontroller. We will discuss the impact of virtualization and how it fulfils the requirements for the safety-critical part all the while allowing to update the non-safety-critical part.

16:55



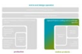
Microservices for Microcontrollers: Allow for easily updating parts of the microcontroller software by deploying a loosely coupled software architecture on microcontrollers
MicroS4MicroC_IRVA

Are you developing connected products featuring microcontrollers running control software with multiple algorithms? This project addresses the growing complexity of optimizing algorithms within specific application contexts. As microcontrollers evolve in versatility and the demand for AI applications rises, the expectation is for algorithms to execute locally.
Manufacturers aspire to ensure that their control software execution aligns seamlessly with the local context, providing the best response to the product's operational environment. To achieve this, the ability to update specific parts of the software code easily is crucial, especially as real-time information is continuously captured from the product's running context. While parameters might have been designed for easy configurability during the initial phase, anticipating all potential future parameter changes remains a daunting task.
Join us in this industrial challenge to enhance the adaptability and efficiency of microcontroller-based systems in the era of connected products.

In this project we will:

- Explore the application of a microservice approach to microcontroller software architecture.
- Identify and evaluate the pros and cons of implementing a microservice-based approach.
- Develop a Proof of Concept (POC) to demonstrate the short update execution cycle for adapting specific algorithms.
- Utilize test information from previous executions to inform and optimize algorithm adaptation.
- Showcase the benefits of retaining microservice capabilities in the kernel for manufacturers of microprocessor software running on Linux.

17:15



Transformer based framework for integrating and interpreting multiscale, multirate and multimodal data in mechatronic systems MULTISCALE_SBO

In this project, we capture the industry's need to integrate data across various scales, including temporal (multirate), spatial (multiscale), and different types (multimodal).

- Companies possess models and extensive data that span different time scales (**multirate/multiscale**), such as the 10kHz PWM cycles of an inverter, 50Hz motor waveforms, or car acceleration and deceleration figures. Often, interactions between these time scales lead to oversimplification, requiring additional modelling effort to run in real-time. This compromises accuracy and hampers the interpretability of deviations between observations and modelled behavior.
- Models, whether physics-based or data-driven, tend to be inflexible when handling heterogeneous data (**multimodal**). Sensor data often demands significant effort for preprocessing and synchronization to align with a model type's requirements.
- Physics-based models can support data-driven modelling techniques on multiple levels, offering faster learning rates, higher reliability, and increased interpretability (if the phenomenon is also modelled). However, there are no clear mechanisms to easily identify the origin of discrepancies between the model and observed behavior.

Transformer models have recently revolutionized the landscape of machine learning-based vision and forecasting, surpassing established methods like long short-term memory (LSTM) and convolutional neural network (CNN) techniques. Transformers excel at handling various data types (multimodal), including vision, and accommodating data at significantly different time scales (multirate/multiscale). Furthermore, the integration of physics-based models has proven effective in reducing memory requirements and training time for transformers. The "attention mechanism" in transformers allows them to interpret the performance of included models.
In the proof-of-concept stage, applying transformers to describe dynamical mechatronic systems has shown promising results. This project aims to advance the state-of-the-art by building a comprehensive transformer-based framework for mechatronic systems. This framework seeks to simplify:

1. Interconnecting multiscale/multirate data,
2. Fusing multimodal sensor data into a single model, and
3. Interpreting observations back to the models on their respective time scales.

In essence, the project aims to:

1. **Reduce the reliance on multiscale, simplified models** of the same component, expediting the modeling process and streamlining multiscale/multi-rate predictions and analysis.
2. **Minimize the need for intensive preprocessing of data sources** (such as vision) before applying them in a predetermined, inflexible model.
3. **Trace back discrepancies in models** (both physics-based and data-driven) for multiple time scales, making them more easily interpretable on their respective time scales.