"Science begins with a vision. Scientific thought is fed by the capacity to 'see' things differently than they have previously been seen." [Carlo Rovelli; Seven Brief Lessons on Physics]

Although considering the scientific perspective, the issue of steel seems to be deeply understood, there are crucial milestones to achieve. The principal goal of this proposal is to glance at the group of nanocrystalline bainitic steels and reveal the fundamental processes of the bainitic transformation kinetics and novel strengthening mechanisms. The different approach to the design of bainitic steels with astonishing chemical composition is a **significant step towards improving the in-use properties of nanocrystalline bainitic steels**, which constitute a critical challenge. The proposed concept focuses on a **synergistic combination of strengthening mechanisms** typical for bainitic and maraging steels. Although this synergy is mutually exclusive at first insight, when considering recent literature reports, it becomes a prospective research direction.

Overall, bainitic steels are characterized by limited in-use properties, which currently pose a challenge. Therefore, our **proposal is a response to current research gaps and at the same time follows EU research directions for the next decade**. This scope of research belongs to the fundamental/basic field of research, however considering a longer timeframe, INSTaBAIN poses potential for technological research and industrial validation. Potential applications include parts exposed to elevated temperatures and requiring high mechanical properties (e.g. *fuel injection systems*, *forging tools intended for warm and hot forming*).

The development of innovative intermetallics-strengthened bainitic steels requires taking *a few steps back* to the foundations of steel phase transformations and reconsidering design principles. The essence of the investigation of intermetallics-strengthened steels is an advanced, dedicated research methodology enabling both qualitative and quantitative assessment of intermetallics and carbides. From a methodological point of view, the scope of this proposal includes the use of niche *in situ* **T**ransmission **E**lectron **M**icroscopy (**TEM**) technique under heating/cooling conditions and tensile stresses, the **E**lectron **B**ack-**S**cattered **D**iffraction (**EBSD**) method, **X-r**ay **D**iffraction (**XRD**) analysis, and the large research infrastructure - **A**tom **P**robe **T**omography (**APT**). It should also be emphasized that the precipitation processes in maraging steels are complex and are still the subject of research by scientists and intermetallic strengthened bainitic steels constitute a niche in this field. Referring to the previously mentioned argument, the principal effort will be directed toward understanding the nickel aluminide (B2 structure, known as β_{NiAl}) growth sequence considering the influence of Cu. Additionally to the design concept of bainitic steels proposed in INSTaBAIN, a series of investigations focused on in-use properties will be performed (*thermal stability*, *corrosion resistance*, *wear*). The effort will be also focused on developing the chemical composition suitable to the **A**dditive **M**anufacturing (**AM**) process using **L**aser **P**owder **B**ed **F**usion (**LPBF**) technology. The use of additive techniques is significant in terms of determining the future applications of these steels, which will enable the production of high-strength structure elements with complex shapes. The general overview of the INSTaBAIN concept is presented in **Figure 1**.

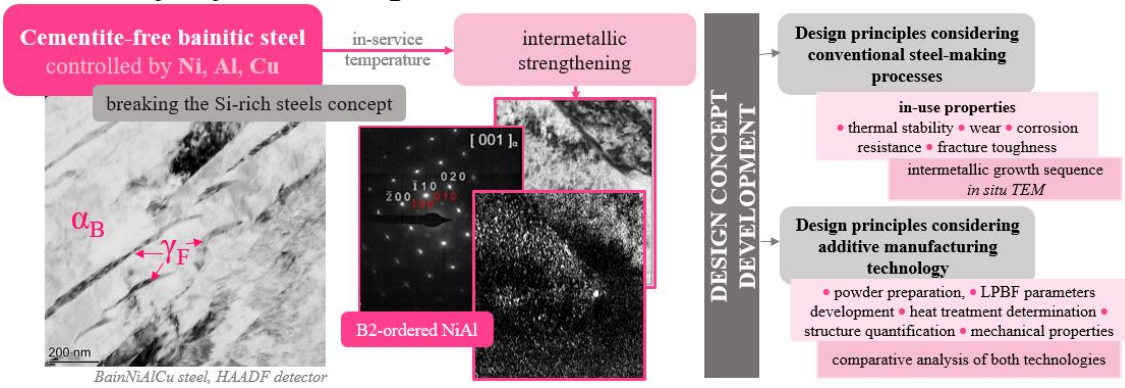

Figure 1. *A general insight into the INSTaBAIN proposal concept*

Performance and durability are at the core of the design concept of INSTaBAIN:

I. Achieve high strength and ductility parameters, which will enable the reduction of the mass of the structure parts. Expected mechanical parameters: UTS > 1500 MPa; YS > 1200 MPa; A > 18 %

II. Enhancing thermal stability – operating at elevated temperatures (up to 550 °C).

III. Wear resistance before and after the influence of elevated temperatures is lower compared to other bainitic steels (considering similar carbon content).

IV. Corrosion resistance is higher compared to other Si-rich bainitic steels.

V. Possibility to produce parts using AM methods to extend the industrial applications