Navantia's Shipyard 4.0 model overview

Vistazo general del modelo de Astillero 4.0 de Navantia

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Abstract

Navantia finished the analysis of the concept Industry 4.0 in 2016 and its application to the naval shipbuilding industry, referred to herein as Shipyard 4.0. The implementation process has begun with several projects that involved various technologies. In order to incorporate them in the new project, for naval vessels and systems, special focus has been put in the future F-110 frigate.

This document aims to provide an overview of the Shipyard 4.0 model and a brief discussion regarding the projects launched for its implementation in Navantia. The initiative 4.0 is a key development vector across all the industrial sectors in the future and its expected outcomes match the ones established by the Government of Colombia in its "Plan de Transformación Industrial" (Plan of Industrial Transformation). In this context, the new frigate program (PES) is a unique opportunity to engage the local industry, in which Navantia offers its willingness to cooperate.

Key words: Industry 4.0, Shipyard 4.0, Navantia, Plan de Transformación Industrial

Resumen

Navantia finalizó el análisis del concepto Industria 4.0 en 2016 y su aplicación a la industria de la construcción naval, denominada Astillero 4.0. El proceso de implementación ha comenzado con algunos proyectos que involucraron varias tecnologías. Para incorporarlos al nuevo proyecto para buques y sistemas navales, se ha puesto especial énfasis en la futura fragata F-110.

Este documento tiene como objetivo proporcionar una visión general del modelo Astillero 4.0 y una breve discusión sobre los proyectos lanzados para su implementación en Navantia. La iniciativa 4.0 es un vector de desarrollo clave para todos los sectores industriales en el futuro y sus resultados esperados coinciden con los establecidos por el Gobierno de Colombia en su "Plan de Transformación Industrial". En este contexto, el nuevo programa de fragata (PES) es una oportunidad única para involucrar a la industria local, en la cual Navantia ofrece su disposición a cooperar.

Palabras claves: Industria 4.0, Astillero 4.0, Navantia, Plan de Transformación Industrial.

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Introduction

All developed countries are concerned with maintaining industrial and innovation capabilities as engines of their economies. After the economic crises of recent years, the contribution of Manufacturing to the GDP and the added value as a percentage of the GDP of most developed countries has fallen. Understanding that there is no sustained economic growth without a strong and innovative industry, there is a global approach to improve industry performances by leveraging new technologies, known as the Fourth Industrial Revolution.

If manufacturing productivity is to be increased and business costs reduced, reforms will have to be made. In shipbuilding, the Colombian Government has developed a plan to for the productive development of the key industrial sector for the Colombian economy, whose purpose is to enhance the competitiveness and productivity of the industry. That Plan is called "Plan de Transformación Productiva[1]" (Plan of Productive Transformation). In it, the Shipbuilding Industry is identified as one of the key industrial sectors.

In order to meet these requirements of improving productivity and reducing business costs, Navantia has implemented the Shipyard 4.0 model. This model aims to apply and optimise the Fourth Industrial Revolution technologies for shipbuilding applications and is being implemented at Navantia's Ferrol shipyard as part of the program to build the Spanish Navy's next-generation F110 frigates. By innovating in core business areas, the Shipyard 4.0 model provides the basis for optimisation of the shipbuilding processes.

Navantia's Shipyard 4.0 Model seeks to deliver the following outcomes

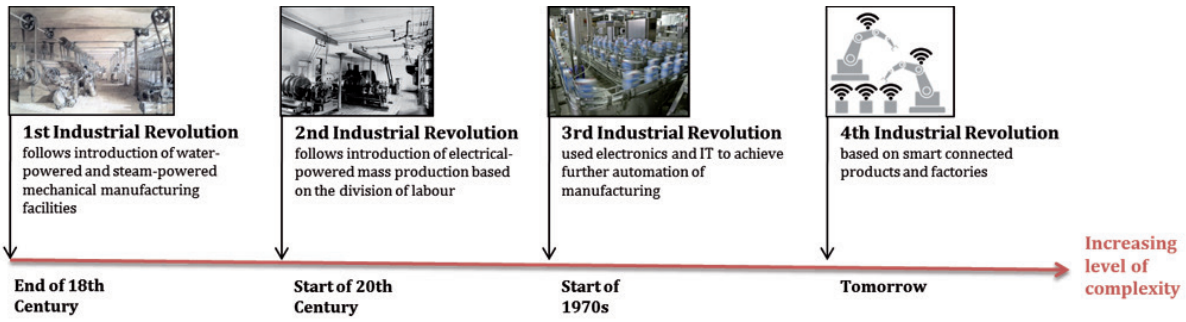
- Creation of a sustainable shipbuilding industry that will deliver the Navy´s future capability through an incremental low risk process;
- Modern facilities that will deliver internationally competitive products;
- Modern ICT (Information Communication Technologies) infrastructure that will support the ships' digital twins; and
- Creation of new skilled workforce able to face the new industrial challenges.

The Fourth Industrial Revolution: Industry 4.0

Throughout the western world new industrial paradigm has surfaced called the Factory of the Future. The Factory of the Future is enabled by the so-called Fourth Industrial Revolution, as a result of technological advances in digitalisation and connectivity.

The challenges originated by this revolution must be addressed without delay:

- standardisation and reference architecture;
- managing complex systems;
- comprehensive broadband infrastructure for industry;
- safety and security;
- work organisation and design;
- training and continuing professional development;
- regulatory framework; and
- resource efficiency.



[1] https://www.ptp.com.co/portal/default.aspx

The 46th World Economic Forum in Davos in January 2016 focused heavily on the Fourth Industrial Revolution. In its report, the Forum emphasised the huge potential associated with the digital change, connectivity and the 'internet of things' for the development of society. Many developed countries have started to pursue this path with government policy being developed to harvest the potential of new digital technologies in order to revitalise the industrial economy of their respective countries, which has shrunk across all Europe (excluding Germany) and in the USA over the past two decades. To this aim, governments, industry, and all relevant stakeholders (universities, unions, media, etc.) have joined forces recognising that the magnitude of the challenge requires a coordinated effort. [1]

This industrial model, often termed Industry 4.0, has four axes:

- vertical integration in a modern factory, aiming to integrate the process from the workshop/ deckplate to top management;
- horizontal integration with Customers and Vendors;
- end-to-end engineering to cover the complete value chain; and
- skilled personnel that respond to the new needs.

The Industry 4.0 doctrine is highly applicable to the naval shipbuilding industry, which combines heavy steel construction work with the most advanced electronics to produce technologically complex products. Naval vessels will benefit greatly from this innovative approach.

General Discussion of the Shipyard 4.0

Introduction

Navantia has recently completed the study and analysis of the Industry 4.0 model [2] for adaptation to shipbuilding. This adaptation has been termed "Astillero 4.0" - in English Shipyard 4.0 - and is currently being implemented. During this phase, projects are being executed to consolidate a range of different technologies with the aim of inserting them in the future ships and systems. Although it is a Navantia initiative, the main project targeted in this implementation phase is the Spanish Navy F110 Program.

The Shipyard 4.0 vision has been presented by Navantia to a range of different forums in Spain, including directly to the Spanish Navy. The vision is outlined in two elements: digitalisation, which is the technological driver of the vision; and the collaboration between all relevant stakeholders which this allows.

Key Elements

With transformative digital technologies, Navantia's Shipyard 4.0 will develop new processes for obtaining the hundreds of systems that compose our ships.

- *Digitisation of all the workshops' machinery* will enable vertical integration through information systems allowing optimisation of the machines' maintenance and energy consumption.
- *Collaborative robotics* will allow people and robots to work together. A range of tasks will be automated, from the more difficult and repetitive, to quality control, or even administrative work.
- *Additive manufacturing*, or 3D printing, will allow the manufacturing of complex component pieces from a 3D model with the same simplicity as printing on sheet of paper.
- *Virtual reality* will allow the development of a 'digital twin' or ship 0 to be created and fully explored ahead of physical construction.

Augmented reality will allow workers easy access to all of the information about any specific component.

- Data mining will allow the extraction of meaningful information from a large amount of data (*big data*) generated in the horizontal and vertical integration of Shipyard 4.0.
- The *Internet of Things* will connect all Shipyard 4.0 stakeholders: people, products, and facilities within the physical shipyard or around the world. This could include geographically disperse supply chains, or allow the connection of shipyards in Ferrol and Adelaide, for example.
- The *secure cloud* will remove the borders for storing, computing, and exchange existing information.
- *Cybersecurity* will ensure the protection of all information.
- *Virtual modelling* will optimise the ships and their systems' configurations in advance as well as simulating the production processes required for their fabrication. The digital twin will be the cornerstone of all the process along the whole lifecycle of the ships.
- All of these measures will directly translate into a significant improvement of personnel health and safety, environmental protection, and an optimisation of energy consumptions.

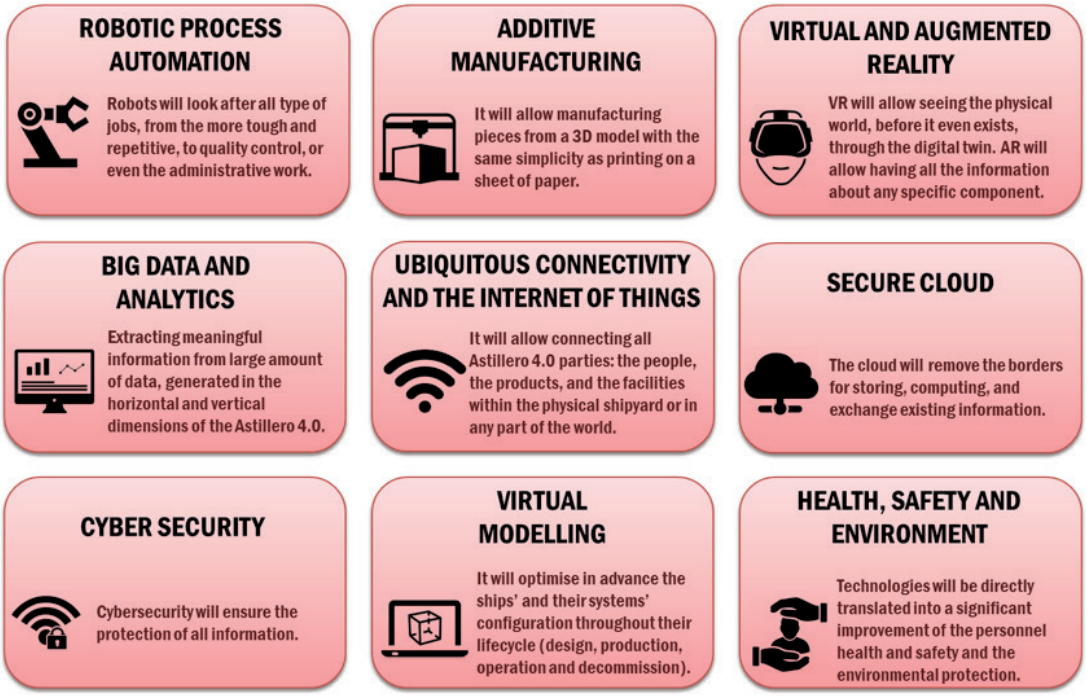
Technological Development

The use of these technologies will allow the full participation of the workshops, docks and different areas of the shipyard with the technicians and administrative personnel – vertical integration. The Shipyard 4.0 physical facilities will evolve alongside the information and communication systems, allowing connectivity between people, products, and machines, creating a cyber-physical space.

The use of on-line production processes sensors and insertion of specialised robots, as well as big data and data mining, will allow for the earlier identification of defects and errors to be corrected in advance. This will greatly improve quality assurance and reduce the risk inherent in complex programs.

In a similar manner, these new technologies will allow a continuous flow of information and materials between the shipyard (centre of gravity of the digital ecosystem) and its customers and

Fig. 1. Shipyard 4.0 Technologies



collaborators, including sub-suppliers. This integrates the value chain from the innovation phase, through to design and fabrication, and continuing through life support service.

This level of horizontal integration allows collaborators to have completely different engagement rules based on a previously unthinkable level of transparency and scope. This allows the incorporation of universities, and scientific and technological centres in addition to the more traditional vendor network.

As a direct consequence, Shipyard 4.0 will be very flexible in the make-control-buy[2] process, which could be adjusted based on the shipyard workload and the facilities capacity, while maintaining the integration function powered by the new digital technologies.

Effective application of the new technologies will require the contribution of engineering (End-to-End Engineering) in all aspects of the Shipyard 4.0, in the vertical and horizontal axes, and through the life of the ships. In this way, Systems Engineering will be used routinely as an integral part of the build process and the shipyard will evolve as a System of Systems.

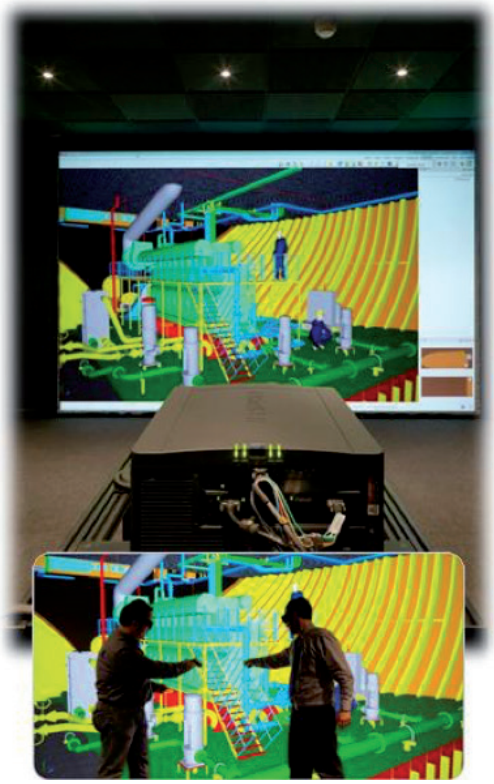
Critically, all of the intelligence and connectivity on board the ships and their systems during their construction will be kept after delivery to the owners, allowing engagement between the *smart ship* and Shipyard 4.0 through their life by enabling *smart sustainment* and new business models.

The 'Digital Twin'

In this highly complex environment – for both the technical and management fields – the digital twin or ship zero will be the cornerstone of the Shipyard 4.0 concept. It will allow the simulation of new products and process developments in virtual work stations. This includes personnel considerations and the reduction of health and safety hazards. [3]

Moreover, the digital twin will be the key element

Fig. 2. Virtual Model Technologies



for enabling the make-control-buy[3] strategy of the Shipyard 4.0. It will allow the different stakeholders to work simultaneously on the digital twin from two perspectives: that of the customer and that of the vendor. This work will happen throughout all product phases: innovation, design and construction, and through the vessel's life.

Obviously, in order to develop the potential of the digital twin and the massive amount of information gathered through the ship's life, it will be necessary to innovate in the rules of engagement between the shipyard, its vendors, and its customers. This innovation will start from the reference customer: the Spanish Ministry of Defence.

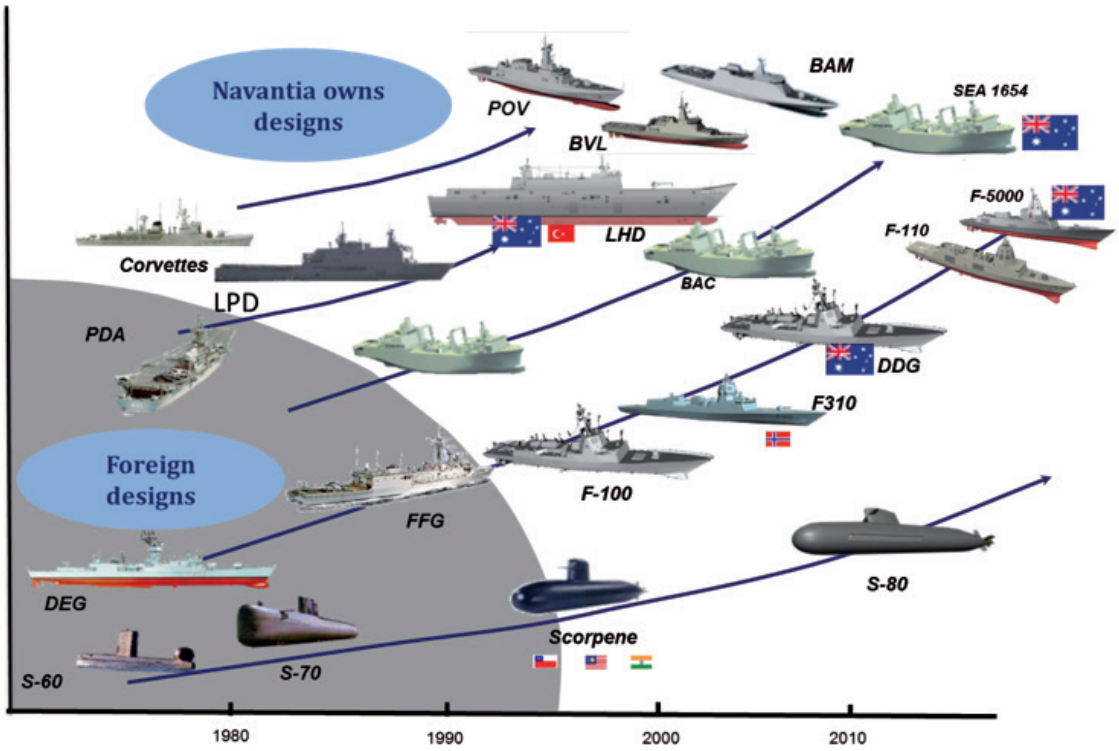
Implementation of Shipyard 4.0

Navantia is currently an international benchmark in the Naval shipbuilding industry because of the

[2] Make: fabricated at the shipyard

[3] Control: procured by the shipyard but with an increased oversight . Buy: procured by the shipyard

Fig. 3. Navantia´s Product Evolution Model



shipbuilding strategy defined and implemented in the 1960s when the Spanish Government started a program to obtain local capabilities. This strategy was performed through the selection of foreign partners; the United States for Surface Combatants, the Netherlands for Logistics and Amphibious ships and France for Submarine development. It was based on small but progressive steps towards a sovereign shipbuilding capability, which Spain achieved by the 1990s. Spain, through Navantia, is now a naval shipbuilding benchmark.

In a similar manner, the Shipyard 4.0 implementation plan must be based on a progressive plan in all Shipyard 4.0 axes (end to end engineering, vertical and horizontal integration and personnel). The materialisation of the concept requires real projects which consolidate the associated technologies and reveal the potential of the digital transformation of Navantia shipyards. [4]. Navantia is currently implanting the following specific projects:

- Modelling and simulation of the production process;
- Digital management of the shipyard plant;
- Additive manufacturing of ship components;
- Shipyard worker vital signs monitoring;
- Automation of the habitation modules fabrication line;
- Automation of the pre-outfit panels line;
- Wireless connectivity on board to reduce cabling;
- Cloud computing of production management processes;
- Factory floor control through Manufacturing Execution System tools; and
- Ship predictive maintenance based on data mining and big data.

These projects complement the R&D activities under the development at the UMI (University and Navantia Research Unit) located in Ferrol and will be added to the initiatives taken by the Advanced Manufacturing Centre in Cadiz (currently under development). The future Advanced Manufacturing Centre will develop projects associated to the following technologies:

- Additive manufacturing;
- Mobile robotics for limited access areas;

- Hybrid laser welding;
- Unmanned vehicles for dimensional control and inspection;
- Production processes and shipyard logistics modelling and simulation;
- Systems rapid prototyping in agile testing environments; and
- Technology demonstrators for transference to the supply chain.

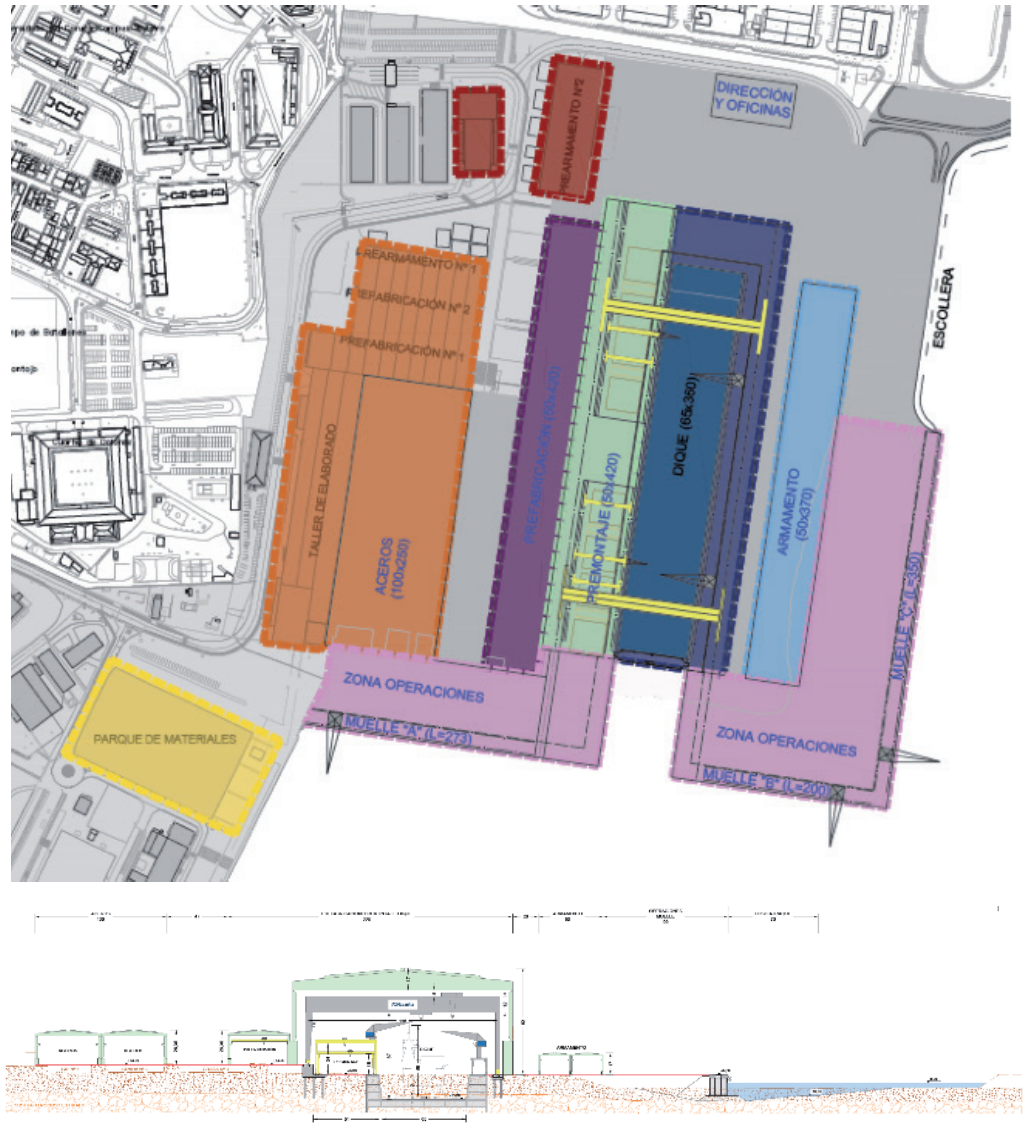
Navantia and Ferrol Implementation

Naturally, fully realising the potential of digital technologies will require changes to physical facilities. For this reason, Navantia has begun a series of shipyard facilities improvement studies. Particularly notable is the Ferrol modernisation project to meet Shipyard 4.0 requirements for the Spanish Navy's F110 future frigate.

As a result of these studies, Navantia has defined a preliminary configuration for the Ferrol shipyard. Key features in this configuration are:

- Building a new dry dock which will allow the complete building of the ships; and
- Construction of the specialty workshops (piping, HVAC, etc.) next to the dock to

Fig. 4. Ferrol shipyard physical modernisation project



minimise distances and optimise the material flow.

The required surface to undertake the shipbuilding process will be reduced by 50%.

The new physical facilities will be enhanced with the most modern digital infrastructure, which will not only allow for monitoring of production within the shipyard facilities but also the vendors' production in their own plants. This will provide greater visibility to the shipyard, as well as greater transparency to the customer throughout the build process.

Navantia is working on the Information and Communication Technologies (ICT) architecture that will support this digital revolution.

Applicability to the Shipbuilding Industry in Colombia

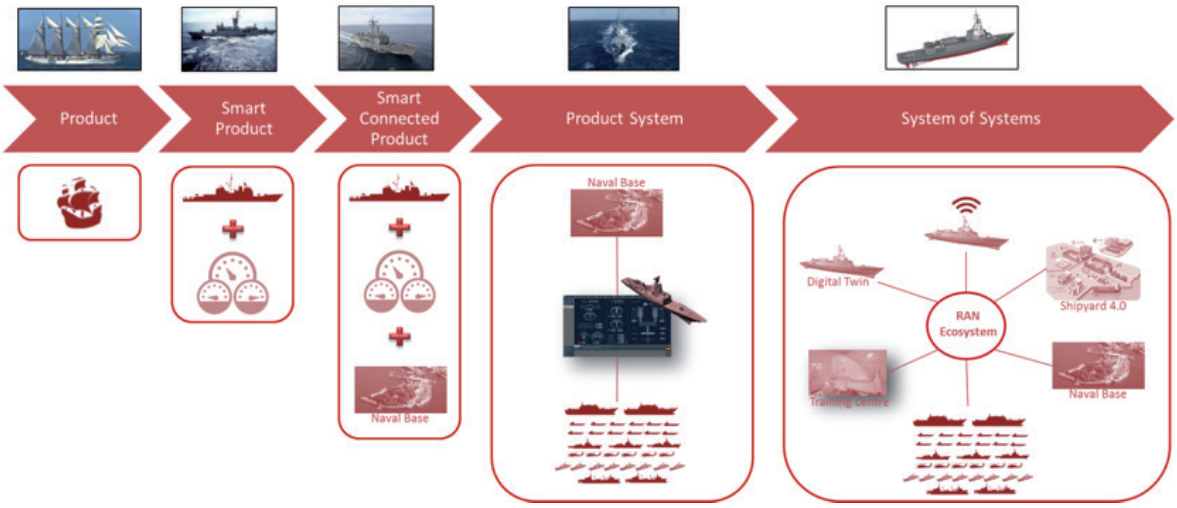
Navantia's Shipyard 4.0 vision could be of great benefit to Colombia as well as Spain. As outlined in this document, this vision is currently being consolidated on specific programs (e.g. F110 in Spain – it could also be applied to Colombia future frigate program) but goes far beyond the ships themselves.

This initiative fits in the strategic view of the Government of Colombia as developed in the *Plan de Transformación Productiva*. The implementation of Shipyard 4.0 in Colombia would require an incremental approach in order to generate the benefits without unnecessarily increasing the inherent technological risks in naval shipbuilding. In this sense, a two batches approach to the shipbuilding program as planned by Colombia would allow significant benefits through a progressive implementation plan of Shipyard 4.0 ensuring that the shipyard, the supply chain, universities and technological centres remain tied to the program development inserting innovation all the way through the program.

In order for this vision to be realised in Colombia, the following will be required:

- A designer integrated with the shipbuilder to accommodate production and sustainment needs;
- A supply chain engaged in the innovation process by improving the connectivity of their products through each batch;
- A redesign of existing facilities to maximise the shipyard productivity levels, allowing them to reach or exceed international benchmarks;
- Defence Science and Technology Group (DSTG), universities and technological centres developing the key technologies that need to be inserted in the ships and in Shipyard 4.0; and
- ICT partners that will support the challenges of the vertical and horizontal integrations.

Fig. 5. Navantia´s vision of evolution from stand-alone Products to System of Systems



Conclusions

The following conclusions can be drawn:

1. Colombia is determined to develop the capacity of its shipbuilding industry. For that, strategic decisions regarding the development of the infrastructure, clustering of the industrial network, local supply chain engagement and cooperation with referenced shipbuilders through transfer of technology agreements are tools for the shipbuilding growth in the long term.
2. Spain commenced a shipbuilding enterprise reform plan in the 1980s, which has consolidated Navantia as a global leader in the shipbuilding industry. Navantia is ready and willing to assist Colombia now to implement its own plan.
3. In the pursuit of continuous improvement and innovation, Navantia has defined the Shipyard 4.0 Model that will enhance the company capabilities in the coming years. The model is holistic and is applicable to all relevant stakeholders. The Shipyard 4.0 implementation plan is collaborative and will be driven by specific innovative projects that will consolidate the Fourth Industrial Revolution in shipbuilding technologies.
4. Navantia is convinced that Shipyard 4.0 can be applied in the Colombian shipbuilding industry in its endeavour to develop an innovative and productive shipbuilding enterprise. This customisation process needs to be incremental to ensure that naval program outcomes are successfully delivered.

Acknowledgment

Thanks to my colleagues in Navantia, in Spain and Australia, who have contributed to this paper in all aspects.

The merits are really theirs.

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