May 15th 2019

S-80 Platform Design for leading edge AIP submarines

Navantia Collins Aerospace

- **The real thing,** operating now in land based test stand, accumulating ‘flight hours’
- **Collaboration enabled success,** combining NASA programs and submarine operation experience
- What’s next…

AIP main characteristics

- Fully automated power plant
- Based on low pressure fuel reforming and PEM fuel cell technologies
- Liquid fuel to maximize endurance

State-of-the-art performance

Full depth range (periscope to MOD)

Long submerged endurance (up to three weeks supporting different navigation profiles)

Minimum contribution to submarine signature: acoustic, chemical traces

Operational safety guaranteed through conventional means and systems

Low toxicity, ease of ethanol handling and stowage

Low operation pressure and minimum H_2 inventory during operation (as it is generated, it is consumed)

Deploy AIP mission anywhere, anytime:

High availability all around the world

No H_2 gas handling, no complex base equipment. No extended refueling time

Bet For BIO fuel:

Consider new threats and environmental sustainability

Focus on the end user (training & operation)

- Designed for the same crew as for a non AIP SSK
- Minimum human intervention, full automation
- Installed power sized to support extended diving without compromising the comfort of the crew

LCS, design compatible with standard SSK ILS

Modular *'plug-and-play'* design: kits embarkable through logistic hatch

No complex maintenance on-board
No programmed maintenance during mission

Design for no major component substitution between overhauls (6 years/>5000 h)

Robust support to AIP engineering and technology development in partnership with Collins Aerospace

- Attribute the success to the collaboration with Collins Aerospace and the Spanish Navy

- Military Fuel Cell and Spanish technology developed for the S-80 are owned by Navantia

- Navalized equipment verified in full scale at land based test and accumulating ‘flight hours’

UTC Corporate History – Marine Fuel Cells

Apollo

Space Shuttle

PureMotion® Buses

Automotive

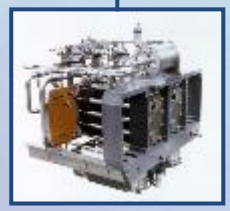
UAV

1958

1960's | 1970's | 1980's | 1990's | 2000's

UUV

Deep Quest UUV



DARPA UUV

PureCell® Model 200

PureCell® Model 400

S-80 Submarine

Collins Aerospace

Navantia

Maritime Systems

Chlorination

UUV Energy Systems

Advanced CO2 Removal Unit

Central Atmosphere Monitoring System

Spearfish Torpedo Power Plant

Air Independent Fuel Cell Power Module

Integrated Low Pressure Electrolyzer (Oxygen Generation)

Collins Aerospace

Navantia

Fuel Cell Power Module Physical Characteristics

Specifically developed to military naval specifications.
Not a commercial based PEM adapted to submarine use.

Operates on Reformate gas, no need for H2 purification.

Operational Life verified to meet the most demanding submarine requirements.

Real World Applications - AC Transit VanHool Buses

FCEB fleet operated 2,057,099 miles and accumulated 248,546 hours on the fuel cell power systems since being placed into service;

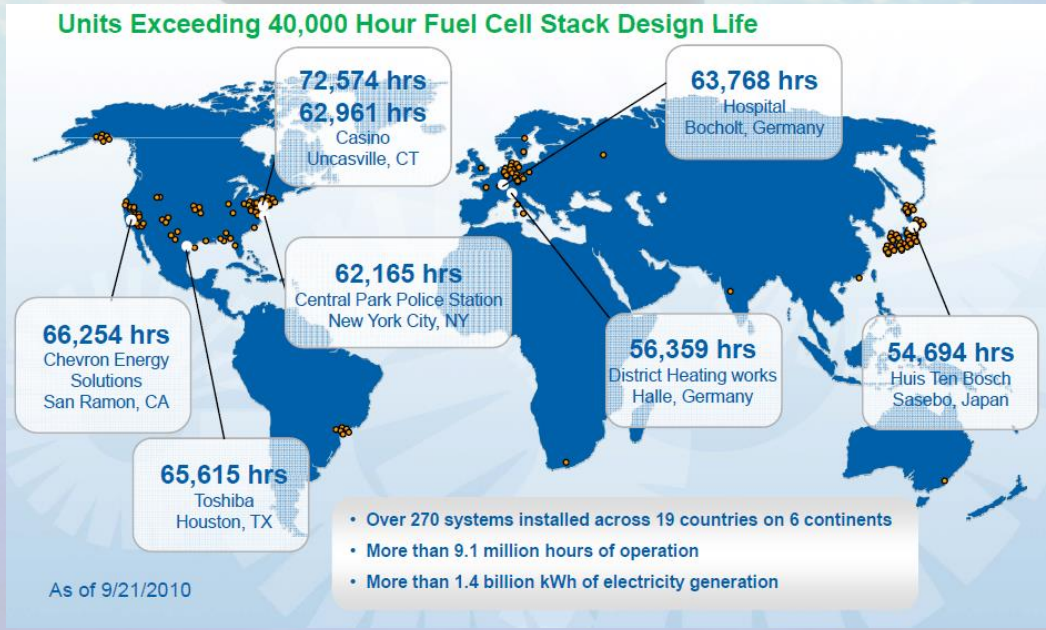
AC Transit has safely fueled its FCEB fleet 3,428 times with more than 76,932 kg of hydrogen fuel;

The fleet leading FCPP (Fuel Cell Power Plant) has surpassed 29,000 hours of operation in a public transit operating environment.

FCEB #7 is one of thirteen zero-emission buses operated by AC Transit. The National Renewable Energy Laboratory (a national laboratory of the U.S. Department of Energy Office of Energy Efficiency & Renewable Energy) documents a series of successes of the AC Transit FCEB fleet.

Data from UTC Stationary Fuel Cells currently operated by Doosan Energy

The design of the PAFC Stack and the MBOP have many shared designs with the Submarine FCPM. This data is for 200 kW unit operating on Reformed Natural Gas and Air

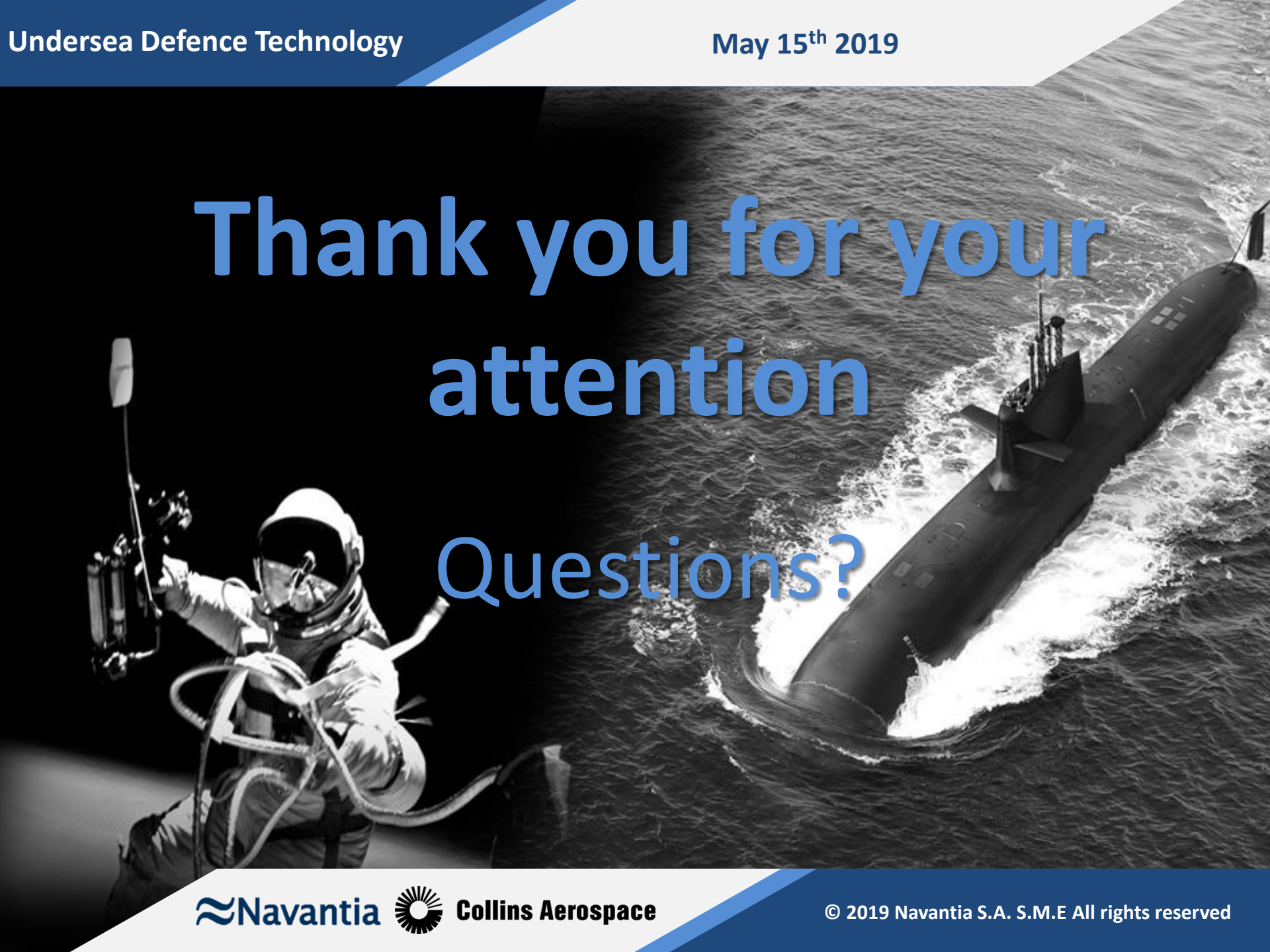


AIP and PEM Fuel Cell as in Spain's S-80 Program

- We have discussed AIP and the PEM Fuel Cell; a **Flexible, Efficient, Proven AIP solution** that also **solves the logistical challenge of safe, readily available fuel**.
- **This AIP is not a concept**, not illustration. Hardware is **developed to military naval specifications**. **Scalable and with a multi platform potential**. Well established Supplier base, meets allied navy standards.
- **Multi year Collaboration between Collins Aerospace and Navantia**, has resulted in an excellent AIP solution, well suitable for modular configurations, ready for the future anticipated variety of solutions.

Collins Aerospace

Navantia



Thank you for your attention

Questions?