Lessons Learned and Challenges from ORION ESM

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Lessons Learned and Challenges from ORION ESM

2014:

- ESA awarded Airbus Defence and Space as prime contractor.
- Scope: Develop & produce the ORION European Service Module (ESM) for ORION spacecraft as part of the ARTEMIS programme.

Challenges & Lessons Learned experienced by Airbus in the last 10 years from a Product Assurance & Safety perspective.

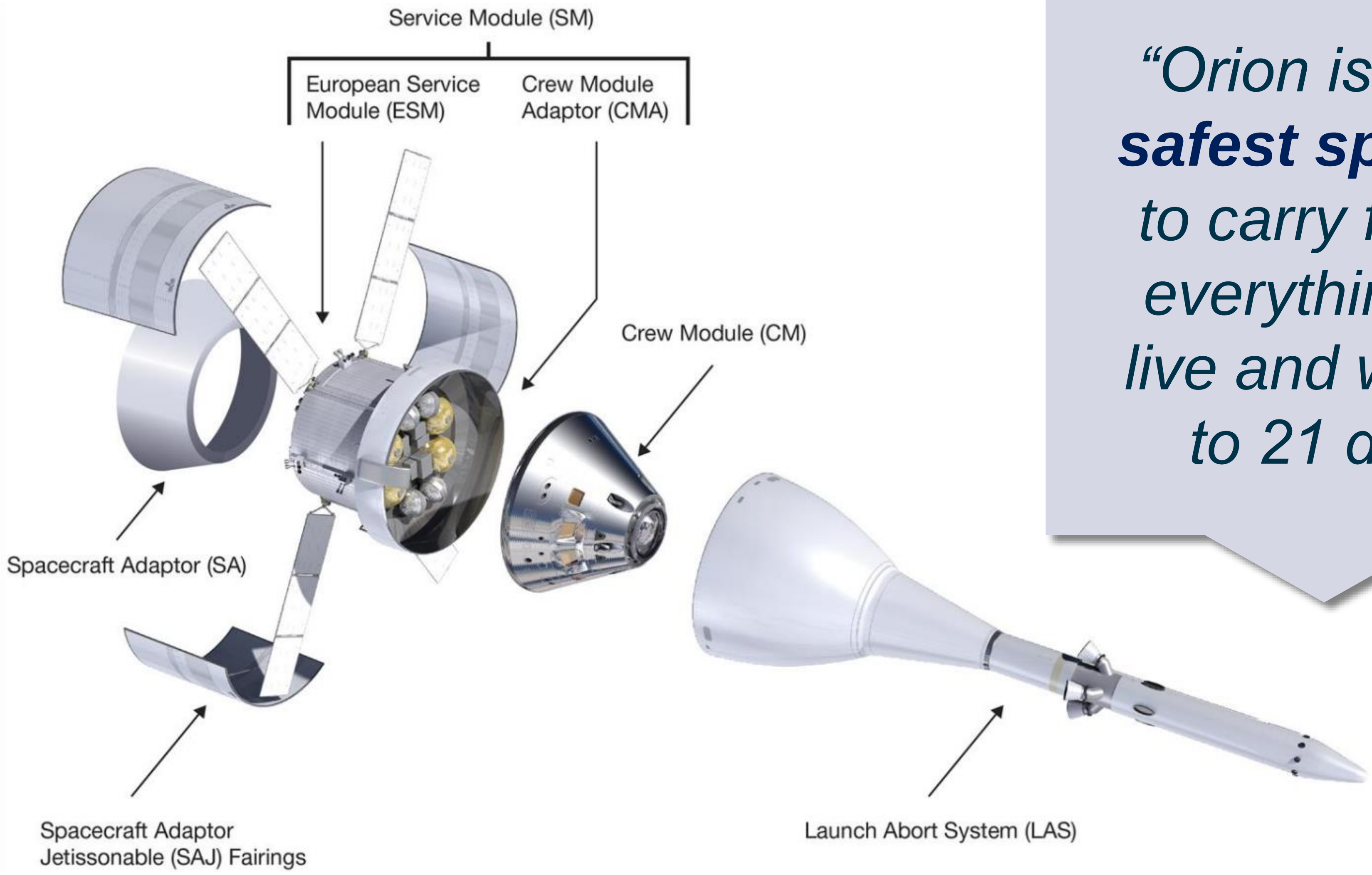
Challenges:

- Multi-purpose mission
- Industrial Setup
- Heritage of involved products & standards

Lessons learnt:

- Hazard Minimisation: DFMR vs. FT
- Design Changes
- Complex Programme Structure; Organisation, Tools and Soft Skills

Challenge: Multi-purpose mission
ORION Product Assurance & Safety challenge



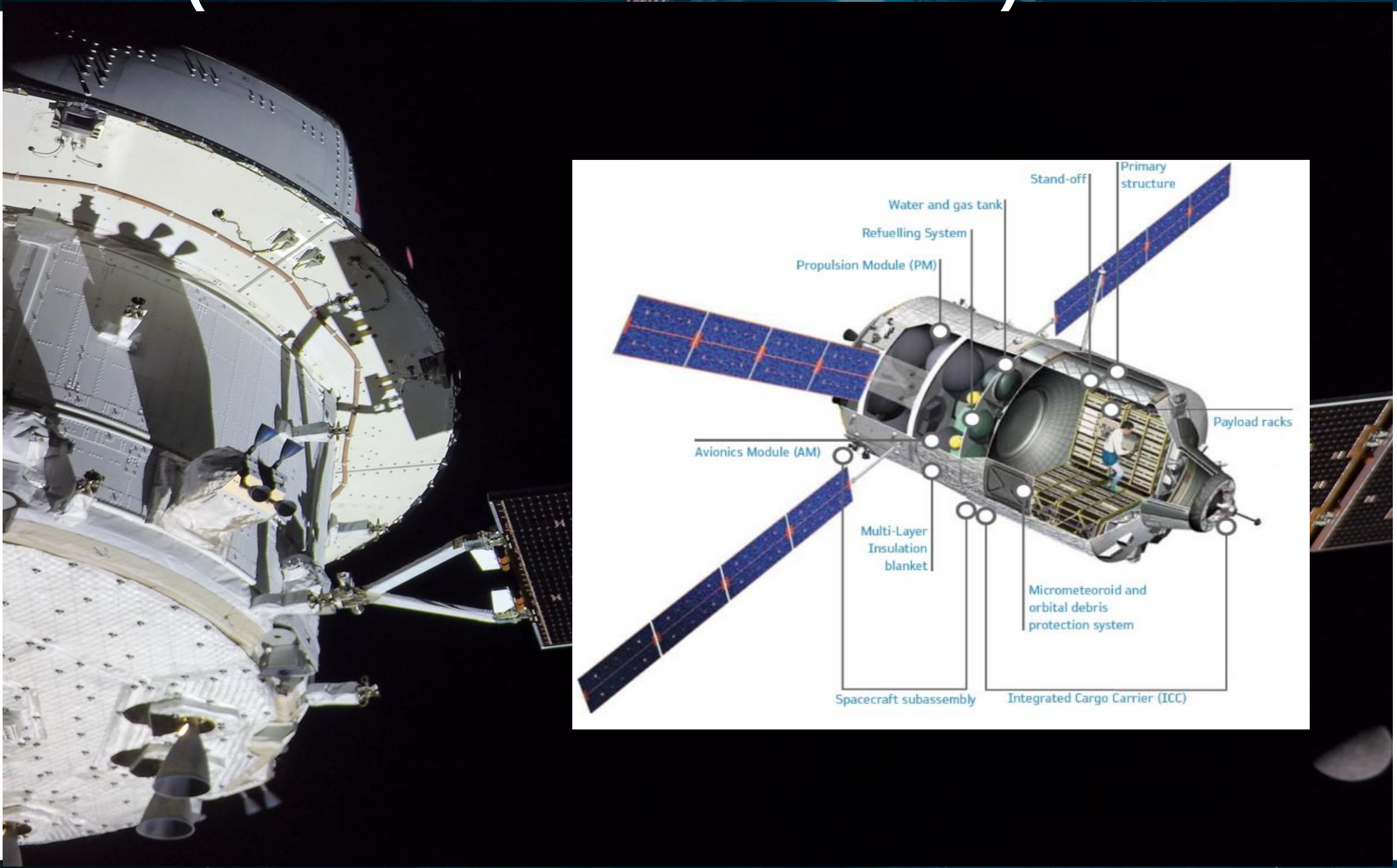
"Orion is designed to be the ***safest spacecraft ever built*** *to carry four astronauts and everything they will need to live and work in space for up to 21 days per mission."*

Challenge: The ESM Industrial Setup
Quality Management & Organisational challenge

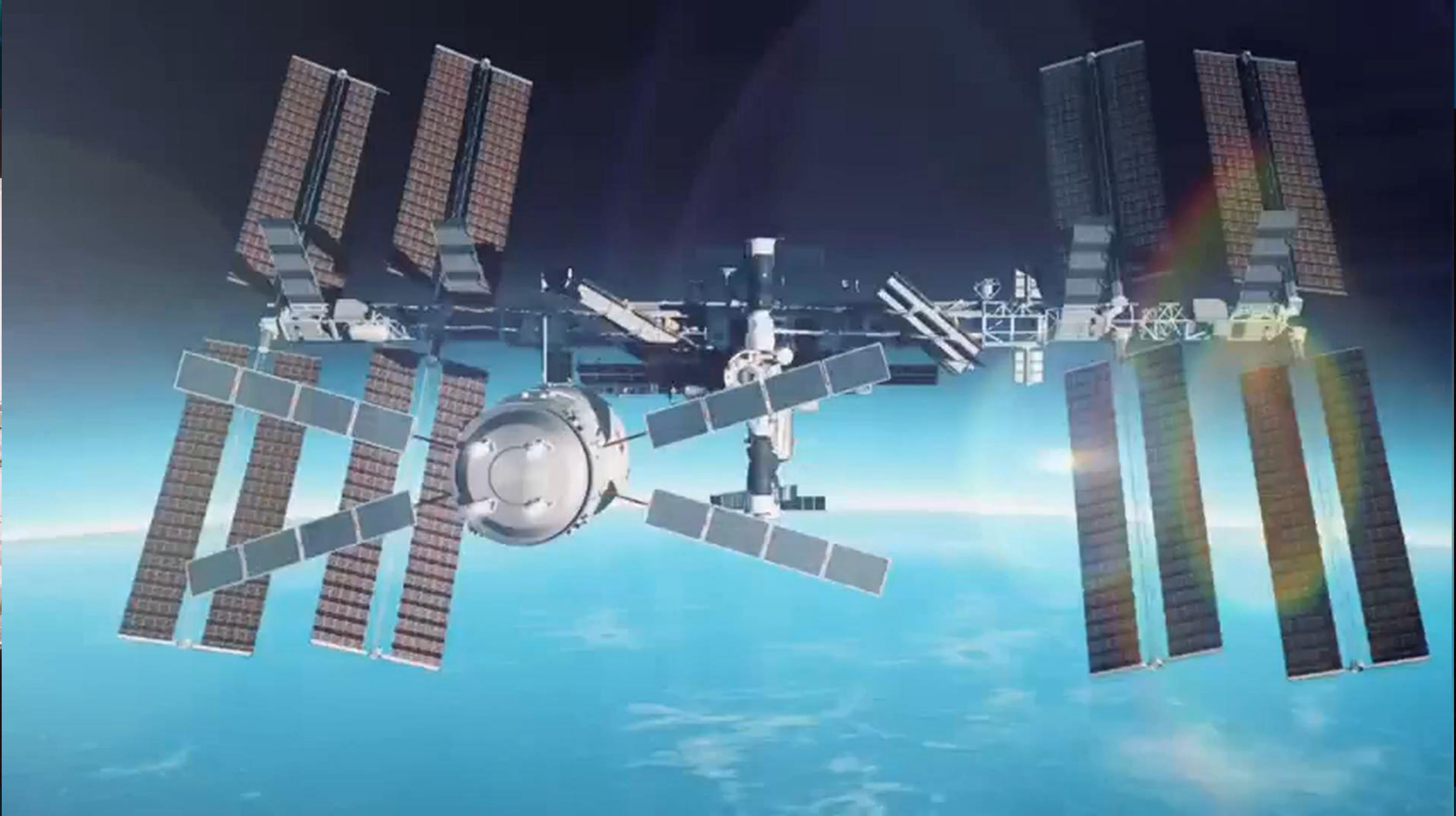
- Project under ESA contract
- NASA is the end-customer
- Airbus as prime contractor
- System engineering split between Bremen and Les Mureaux
- Lockheed Martin is responsible for the Crew Module and the end-to-end final integration
- Subcontractors selection must fulfill ESA geo-return requirements

Airbus Defence and Space GmbH	Project management, system engineering, AIT & ground operations management
Airbus Defence and Space SAS	System engineering
Airbus Defence and Space Netherlands B.V.	Solar Array Wings (SAW)
Airbus DS Space Systems Inc.	U.S. interface
Computadoras, Redes e Ingeniería, S.A.U. (CRISA)	Thermal Control Unit (TCU)
Tesat-Spacecom GmbH & Co. KG	EEE for PDE
ArianeGroup SAS	Engineering support, ESM-QF, software, pressurant tanks
ArianeGroup GmbH	Engineering support, AIT, PCA, RCS, Fill & Drain Valves, Propellant Tanks, Propellant Management Device, PSS tubing
Thales Alenia Space Italia	Structure, CSS subsystem, thermal control
Thales Alenia Space Belgium	Pressure Regulator Unit (PRU)
Leonardo S.p.A.	Power Conditioning and Distribution Unit (PCDU)
RUAG Schweiz AG	Solar Array Drive Assembly (SADA)
Lockheed Martin Space	Pyro Valves
Latécoère Interconnection Systems	DC harness
Filcon Electronic GmbH	ODN harness
Adcole Maryland Aerospace	Sun sensor
VACCO Industries	Auxiliary propellant filters
Clemessy S.A.	EGSE maintenance

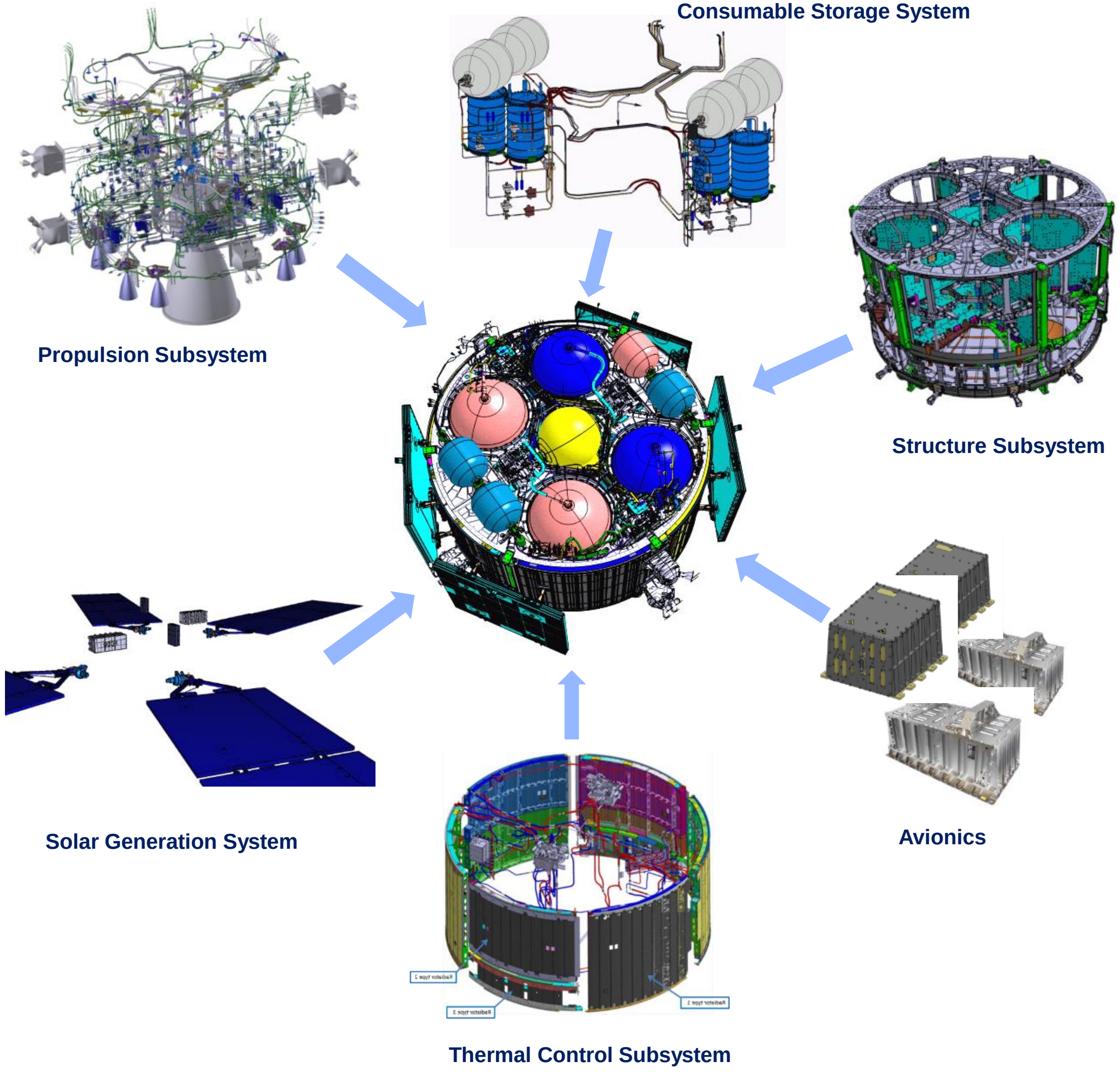
Challenge: The ESM Heritage Programme ATV (Automated Transfer Vehicle)



- Developed by Airbus / ESA 1995 – 2007
- 5 vehicles flown to ISS between 2008 & 2014
- 20 ton cargo (8 ton payload) vehicle to supply the ISS
  - Gas, water, refueling, propulsive support, payloads
- Autonomous ISS docking capability
- Designed against
  - ECSS tailoring
  - Compatibility with Ariane 5



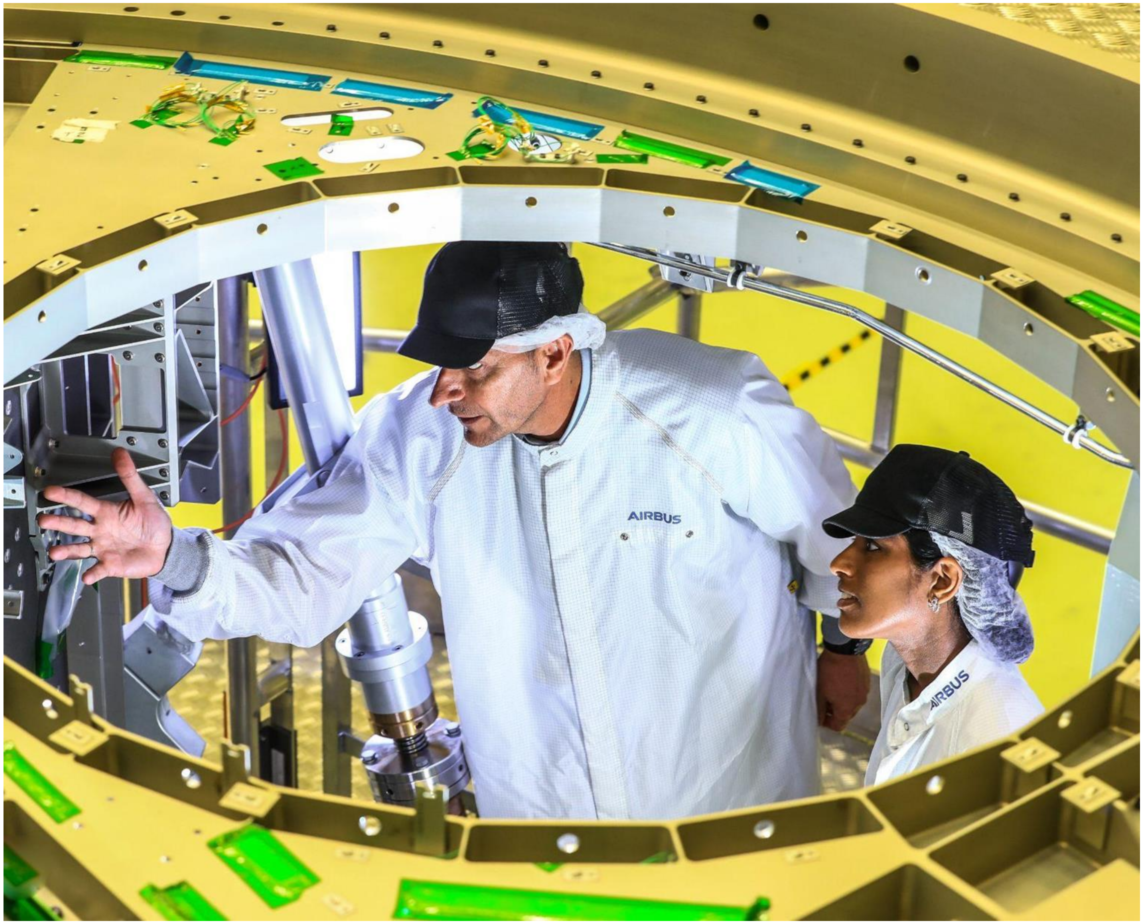
The ESM Design
Various General Challenges compared to heritage



- "Multi-Purpose" vehicle
  - Lunar flyby mission / Crewed lunar rendezvous / ISS supply missions
- Industrial set-up
  - ESA / NASA / Lockheed Martin
  - ESA geo-return
- Shuttle heritage equipment
  - OMS-E and TVC
- Requirements changing during the project
  - New launcher upper stage, varying mission scenarios, NASA developing vehicle operations
- European versus U.S. standards
- Very tight budget & schedule

Lessons Learned: Hazard minimisation
Design For Minimum Risk (DFMR) vs. Failure Tolerance (FT)

Late agreements on philosophy & requirements for minimising hazards



DFMR only accepted for certain predefined items:

- ESM Primary structure
- Structural failure of pressure vessel walls
- Structural failure of pressurised lines & welded joints

Items declared "0-FT treated as DFMR":

- Secondary structure & Cold plates
- Radiator & SAW hinges
- tank bearings

Items not accepted as DFMR:

- Single seals & valve bellows
- Pressure Transducer diaphragm & SADM mechanism
- SAW panel hinges and release & deployment mechanisms

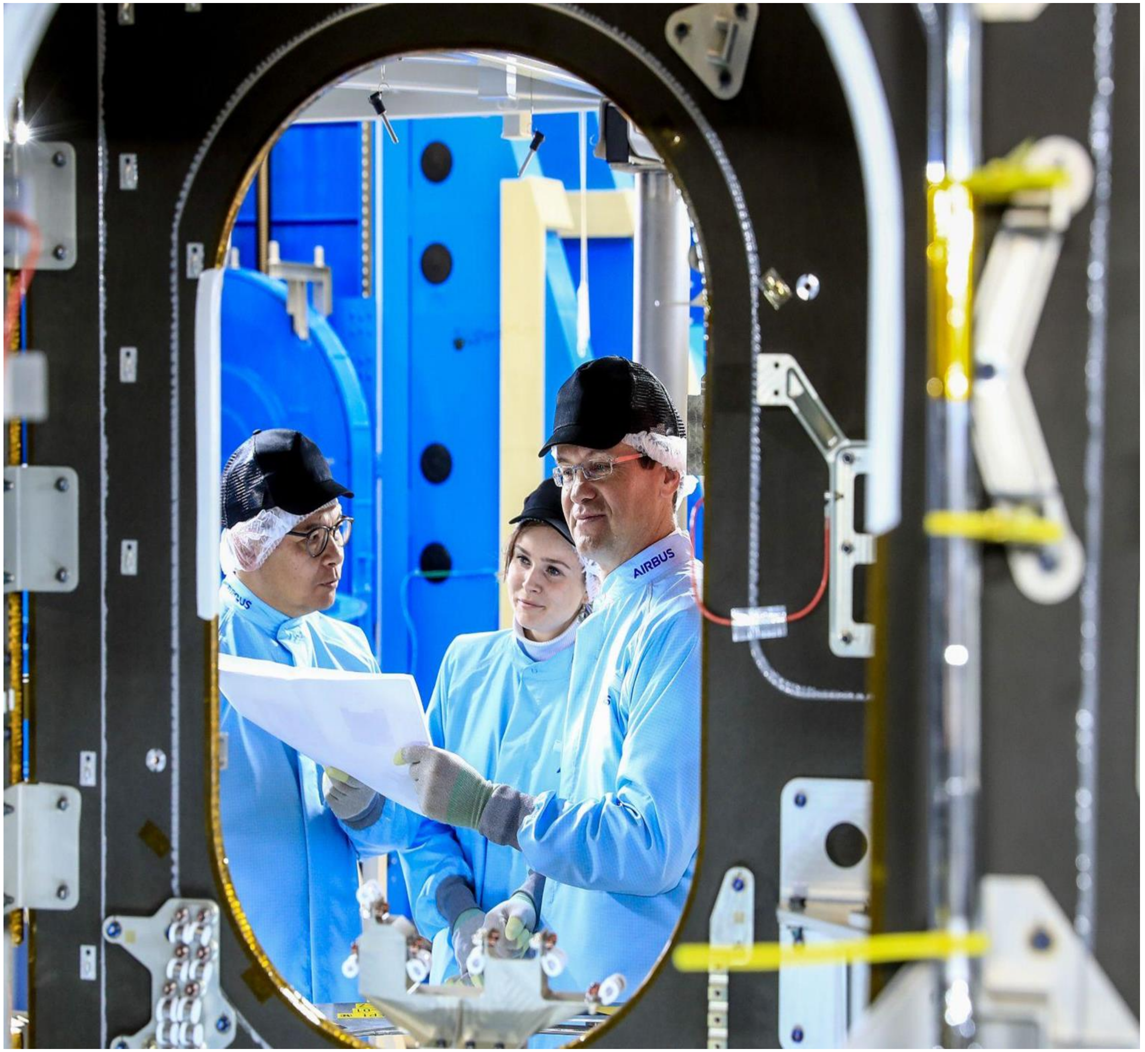
→ **Zero-FT exceptions with significant verification effort**

Additional qualification & acceptance requirements for pressurised valve bellows

→ **Partial re-design of heritage equipment**

Secondary containment for valves & pressure transducers

Lessons Learned: Design Changes



To meet the changes on system level for design improvements

Various PA and Safety requirements modified during development phase

Impacting the detailed design of subsystems, assemblies and equipment

Decision to start FM manufacturing before qualification

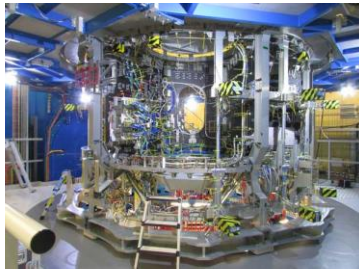
- Qualification campaigns: ex. whilst ESM-1 hardware was already in System AIT
- Testing, of ESM-1 FM whilst ESM-2 hardware was already produced & System AIT started

Lessons Learned: Design Changes

Late changes in the design and operation of the subsystems & equipment were introduced → **Varying applicability of the ESM´s** → E.g. operation of Pressure Control Assembly to cover identified behavior of valves

Design Changes Driven by

- **outcome of the DFMR vs FT** →
  - Additional Safety heaters for all critical equipment.
  - Double insulation in Power Control & Distribution Unit (PCDU),
- **other evolutions of requirements due to late design definition.** →
  - Redundant back relief valves in all thruster branches
  - Solar Array Wing (SAW) deployment monitoring (latch indicator re-design)



Bremen, G
Airbus
System and AIT

White Sands, USA
NASA
PQM hot firing tests

Plum Brook Station, USA
NASA
Environmental and structural test

Les Mureaux, F
Airbus / AGG
Functional V&V

Denver, USA
LMCO
ORION S/C Simulation

KSC, USA
NASA
ORION S/C Integration

Lessons Learned
Complex Programme Structure

Organisation, Tools and Soft skills

The complex industrial setup leads to a high number of stakeholders

- Programme is largely managed **online** with only few physical meetings (such as QPM’s)
- **Powerful tools** for online meetings needed (certified for export control requirements)
- Attention: There are different **IT security requirements** between Europe and the U.S.
- **Distribution of information**, including **export control** compliant data management.
- Dedicated certified software platforms and secure servers needed.

→ Investment in IT infrastructure and Tools, including personal equipment of the team members

For standard PA&S processes, high number of stakeholders

- Number of NRB participants >50 persons online.
- Demanding PA Manager role as Chairperson.

→ Training of the PA&S team members on Softskills and Communication

Summary Lessons Learned and Challenges from ORION ESM

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THANK YOU


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THE SKY IS NOT OUR LIMIT
Proudly at the heart of the return to the Moon