A400M aircraft. Design Requirements & Conceptual Definition

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DEFENCE AND SPACE

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Introductory video (Air Transport Aircraft in Europe)

Historical background of A400M

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Historical background of A400M (1)

Industry: In 1984 it was established a Working Group with representatives of Aerospatiale, British Aerospace, Lockheed and MBB to define the basis for the future substitute of the C-130 Hercules and the C-160 Transall. It was called Future International Military Airlifter (FIMA). Later on, Alenia and CASA joined it and Lockheed abandon the group. The new group was called EuroFLAG (European Future Large Aircraft Group-Euroflag).

Nations: In parallel, the MoD and AF of some European nations were trying to jointly define the requirements for such future aircraft; with the feedback and contribution from Industry.

- The initial targets from six countries were agreed in 1991

  O.E.S.T. (OUTLINE EUROPEAN STAFF TARGET) ➔ (Origin of Pre-Feasibility Studies)

- Harmonization process on operative targets were agreed in 1993

  E.S.T. (EUROPEAN STAFF TARGETS) from seven countries

- Final establishment of design requirements between eight countries in 1996

  E.S.R. (EUROPEAN STAFF REQUIREMENTS) for a Future Large Aircraft ➔ **ESR Document**

- First Request For Proposal (RFP) issued to Airbus in 1997. Final open competition RFP issued in 1998.

Historical background of A400M (2)

On the basis of the ESR Document:

- A first PDP (Pre Development Phase) contract was agreed between the launch Nations and the Industry to allocate limited funding for conceptual definition and pre-feasibility studies for the design of the future aircraft (e.g. Wind Tunnel Test for configuration validation)
- Industry Commercial Proposal to Nations RFP presented to the Customers in 1999.
- A400M was selected in year 2000 and a MoU signed at Le Bourget Air Show in June 2001 (9 Nations)
- In December 2001 the DPP contract was agreed between OCCAR (Organisation Conjointe de Coopération en matière d'ARmement) representing 8 European Nations (France, Germany, United Kingdom, Spain, Belgium, Luxembourg, Portugal and Turkey) and AMSAS, but still subject to Parliaments approval.
- DPP Contract was formally launched (Entry into Force) and signed between AMSL and OCCAR (7 Nations) in March 2003. (Just after selection of Power Plant by Industry)
- The Exhibit A of the Contract (Technical Specification) + other Exhibits collected all the detailed technical requirements to fulfil the ESRD needs and to be used for the design and development.

A400M Design Requirements

ESRD requirements covered many topics. They were “translated” into the Contract; technical ones mainly in an Exhibit A, in terms of Technical Specification Requirements (around 2.700 TSRs). They include:

- General characteristics (Mission needs, payload, hard points, variants and options, etc.)
- Design standards and criteria (Airworthiness, loading, structure, safety, reliability, environmental, noise, handling characteristics, software, human factors, growth potential, etc.)
- Special AC characteristics
  - Mission and performance requirements, Survivability, Vulnerability, INFOSEC, TEMPEST
  - Fight and cargo compartments characteristics (floor, ramp, cargo handling system, loadmaster station, equipment configurations, etc.)
  - Aerial delivery operations (Loads by gravity or extraction, paratroopers, mixed AD, CARP, Automatic AD)
  - Communications, navigation, monitoring & diagnostic, recording, AAR sub-systems, DASS, etc.
- Other requirements (Power Plant, APU, Electrical, Landing Gear, Lights, Air Conditioning, etc.)

Also Integrated Logistic Support (Ground support, AGEs, maintainability, technical documentation, etc.)

On top of it, additional Industry internal requirements were collected in a Top Level Aircraft Requirements Doc.

A400M Design Requirements
General objective was:

Video
A400M The Versatile Airlifter

Tactical Capability:

- Low level operation
- Autonomous loading and turn-around
- Ability to use short/soft unprepared airstrips
- Reversing capability
- Steps descent and climb out
- Air delivery of droops and cargo

Strategic Capability:

- High cruise speed / long
- Voluminous cargo hold
- Loading light vehicles side by side
- Transport of all relief materials in pallets
- Capable of carrying heavy machinery
- Casualty evacuation: up to 66 stretchers

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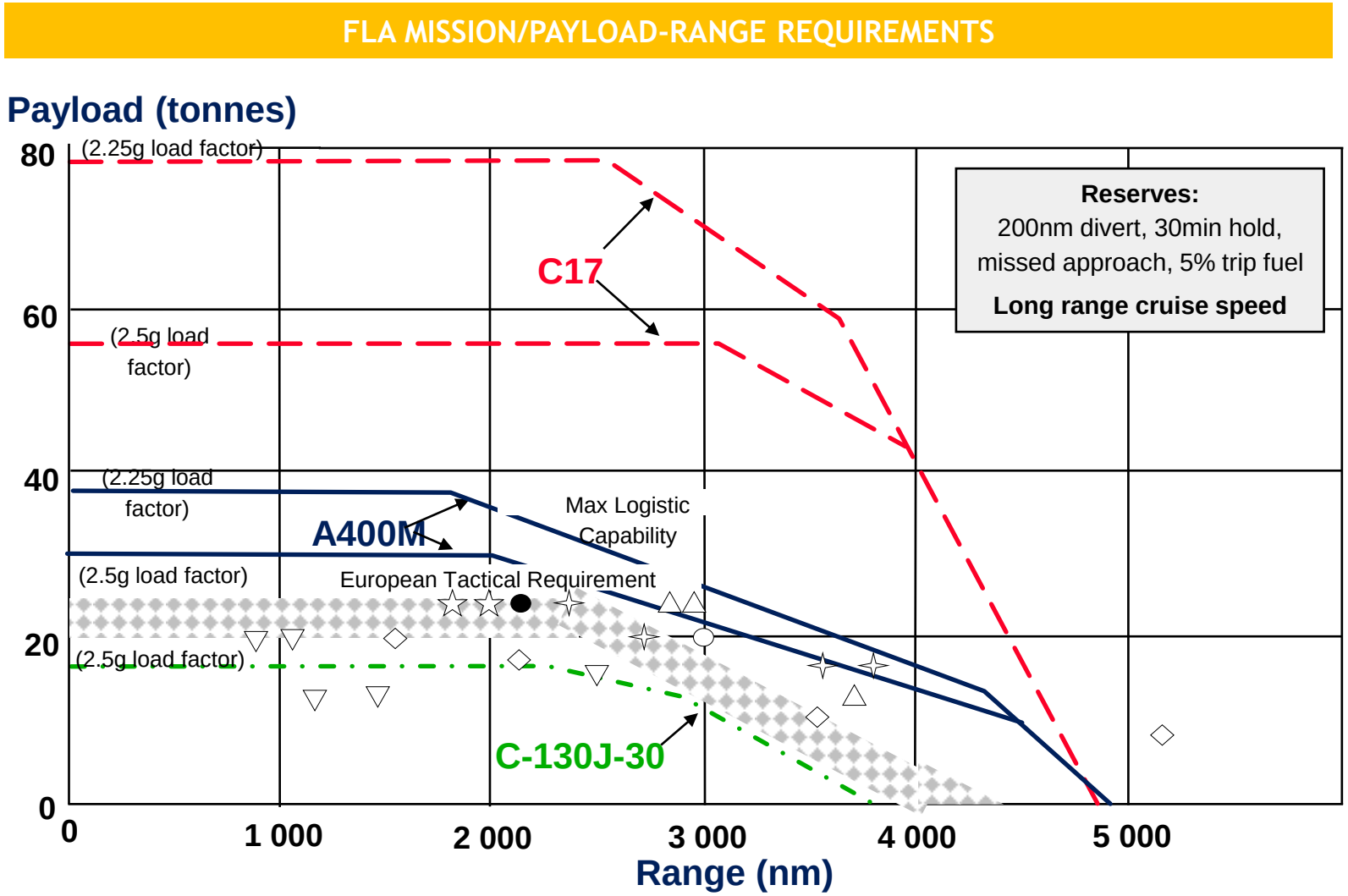
Design Requirements

As a result of the mission requirements the figure shows the comparison with competitors in terms of Payload-Range diagram



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Competitors

❑Antonov An-70

- ▪Same Cargo Hold dimensions and footprint as the A400M.
- ▪Accommodation of 300 troops in two decks but not compatible with JAR-25 safety requirements
- ▪Shorter and steeper ramp limiting the loading of outside loads
- ▪Higher maintenance level and noise due to propeller fans
- ▪No clear program roadmap: as of 2015, status of Ukrainian orders is unknown - only one prototype in-service.

❑Antonov An-178

- ▪Positioned between the C295 and C-130J-30, with a specific version which incorporates western engines and avionics
- ▪Half of the A400M cargo hold volume with half of the length and width
- ▪Half of the maximum payload with limited range
- ▪Jet engines limiting unpaved airstrip capability and tactical flight at low speeds and altitudes.

❑Boeing C-17A Globemaster III

- ▪Designed in the 1970s to meet specific in-house USAF requirements resulting in an aircraft with strategic capabilities and very limited tactical capabilities
- ▪Not able to operate onto unpaved airstrips due to its jet engines which are more subject to FOD ingestion
- ▪A400M cargo cross section which has the same height restrictions as C-17A
- ▪The production was stopped in 2015 as international interest was low (high price tag and expensive operating costs) with only 52 export aircraft ordered by 8 countries outside the U.S. in 15 years.

Competitors

❑Embraer KC-390

- Severe limitations for tactical missions and also limited capabilities for strategic transport missions
- Jet engines limiting unpaved airstrip capability and tactical flight at low speeds and altitudes
- Limited cargo capabilities due to smaller cargo hold dimensions and lower payload
- Limited aircraft range and fuel giveaway capability for AAR missions.

❑Ilyushin Il-76MD-90A

- Based on 1960's Il-76 aircraft
- Shorter and steeper ramp limiting the loading of outside loads
- Jet engines limiting unpaved airstrip capability and tactical flight at low speeds and altitudes
- High fuel consumption of jet engines increasing operational costs.

❑Kawasaki YCX/XC-2

- Designed to answer the specific Japan Air Self-Defense Force's requirements – only 3 aircraft on order
- Fitted with turbofans which are vulnerable to FOD ingestion when operating from unpaved airstrips
- A less capable mini C-17A with limited tactical or military capabilities
- No air-to-air refuelling capabilities.

❑Lockheed-Martin C-130J / C-130J-30 / KC-130J Hercules

- Modernised versions (new engines, glass cockpit, upgraded systems) of 1950's C-130A
- Small cargo hold making impossible the transport of today's vehicles which are heavier and bigger
- C-130J is half the payload and cargo volume of A400M and goes to shorter distances
- KC-130J is a single role dedicated tanker version with limited fuel capacities and no 3rd refuelling point.

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Alternative concepts/configurations

Selection of the reference aircraft concept:

Evaluated concepts:

- TWIN TURBOFAN AIRCRAFT
- 4 x TURBOFAN AIRCRAFT
- 4 x PROP-FAN (CRP) AIRCRAFT
- 4 x HIGH SPEED TURBOPROP AIRCRAFT

Reference concept final selection: **4 x High speed Turboprop**

- 2 x Turbofan: very similar weights (+2%) but smallest mission reliability
- 4 x Turbofan: 10% heavier and difficulties in tactical operations
- 4 x Prop-Fan: 2% lighter but high risk because of Power Plant development

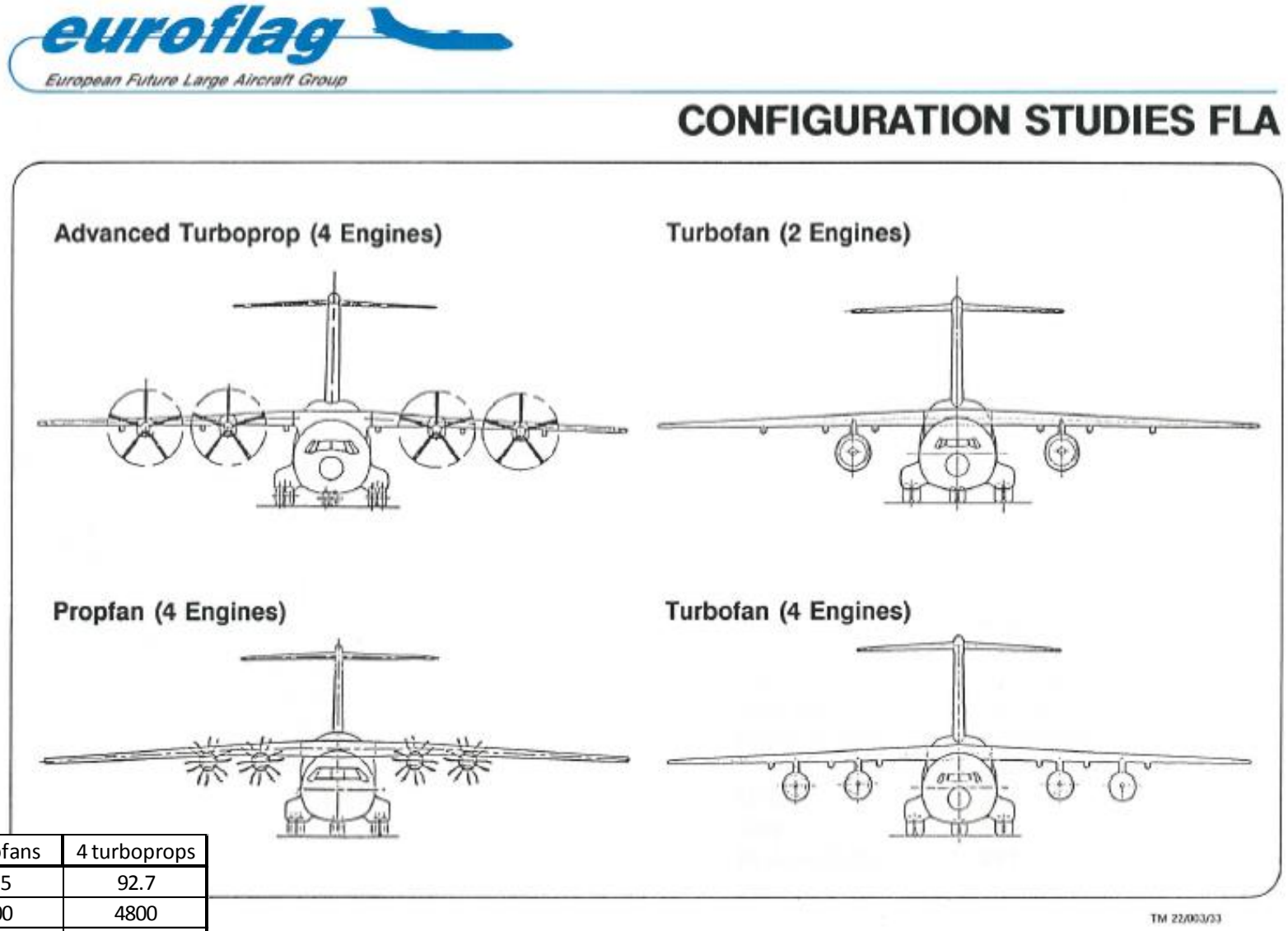
Alternative concepts & configurations

In the early 90´s a trade off was performed between the previously mentioned Power Plant configurations.

- Lower weights and TO/Landing distances better for prop-fan & turboprop
- Also, prop-fans & turboprops show better steep descent and back up capabilities (commanded blade angle), so as in the landing distance
- Also lower weights for prop-fans and turboprops

Main figures of merit are as follows:

	4 Turbofans	2 Turbofans	4 propfans	4 turboprops
MTOW (Tons)	100.9	94.9	91.5	92.7
Mil TO distance (ft)	5000	5200	4000	4800
Mil Landing distance (ft)	2950	3200	3000	2700



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Configuration and Power Plant selection

Power Plant selection affects overall A/C performance and is driven by specific A400M military requirements :

- Payload/range. Affected by A/C weight (MTOW) , which includes fuel consumption.
- Specific A400M tactical requirements, mainly:
  - Short Take Off and landing distances, affected by wing integration effects and reverse thrust capabilities
  - Cruise maximum speed. High speed for turboprop. Low speed for turbofan.
  - Steep Descent capabilities.
  - Back up capabilities on ground.

Technical merits were traded off against overall project risk, mainly engines, prop-fans, propellers readiness/availability.

Final decision for a turboprop power plant was based on:

- Propeller & prop-fan options show better characteristics in particular for tactical capabilities.
- Selection between prop-fan and turboprop was based on technology availability.

Even if prop-fans show better performance, the technology was judged to be high risk. only Antonov 70 implements similar technology (counter-rotating propellers). Other constraints i.e. noise characteristics.

- A number of turboprops were in service with well known technology. Integration challenges known

Final selection was for a turboprop: Core engine available but still challenges for high speed/large size propeller, and high power Propeller Gearboxes.

Impact (effect) of specific military requirements

It is worth full to highlight some of the design features derived from the specific military requirements, and their effect on the aircraft characteristics (e.g. speed range, maneuverability, ground maneuvering characteristics even on unprepared runways, survivability in hostile environments and the capability to transport and aerial delivery of heavy loads and paratroopers)

Such requirements have driven in a significant way the architecture, selection and design of some of the main aircraft systems, as for example the Power Plant, the Landing gear, the flight controls and Control Laws, communications system, cockpit layout (NVG compatible), cargo handling and aerial delivery system and defensive subsystems (DASS).

Impact (effect) of specific military requirements – Cargo Hold

A400M Cargo Hold Flexibility

Leading requirements:

- Maximum Payload → Aero Loads, Structure, floor strength, hard points
- Payload Volume → Cross section
- Payload Volume → CH length
- Payload type → CH configuration and cabin systems
- Autonomous ops. → Cargo Winch, Crane, Kneeling system
- Cargo Handling System

Vehicles and Helicopters

10/20/30/40 ft ISO Containers

9 Pallets and 54 Troops

116 Troops or Paratroops

110 Palletised Seats

66 Stretchers and 25 Medics

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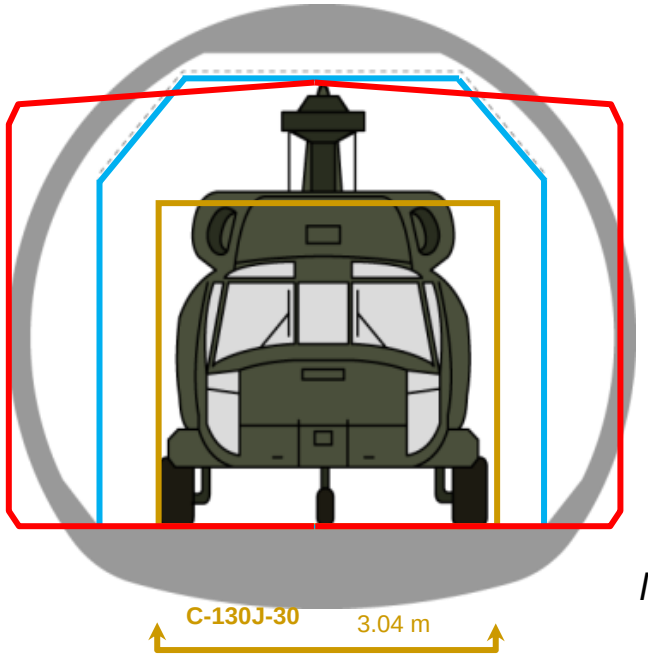
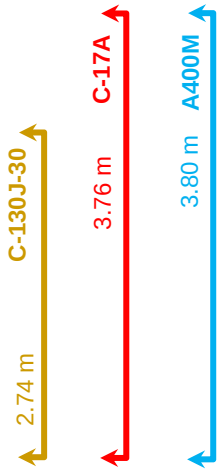
Impact (effect) of specific military requirements – Cargo Hold

Cross Section and overall dimensions

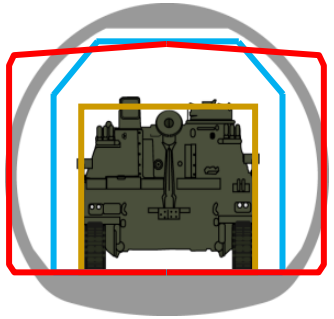
UH-60 Blackhawk *Helicopter*



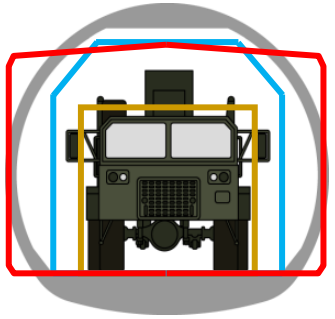
Minimum Widths



Minimum Heights



M109 *155mm*
Self-Propelled Howitzer



Patriot
Missile Battery

Able to carry a wide range of loads that cannot be transported in current tactical airlifters

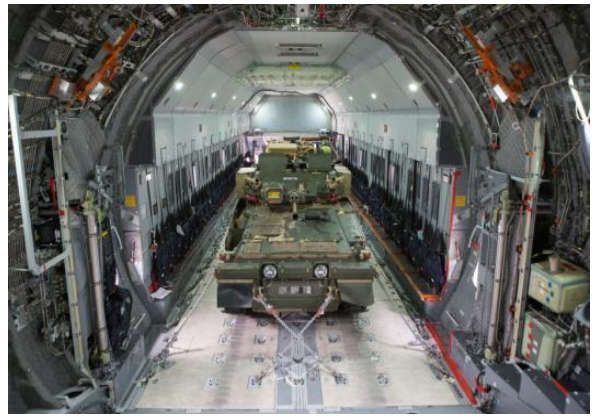
Impact (effect) of specific military requirements – Cargo Hold

Few Examples of Loading

Video
Up-Loading / Down-Loading

VBCI infantry fighting vehicle (28 tonnes)

20-ft ISO container



Scimitar armoured vehicle (7.8 tonnes)

Oshkosh 1500 fire brigade truck (26 tonnes)

UH-1H (x2) transport helicopter

EC725 transport helicopter

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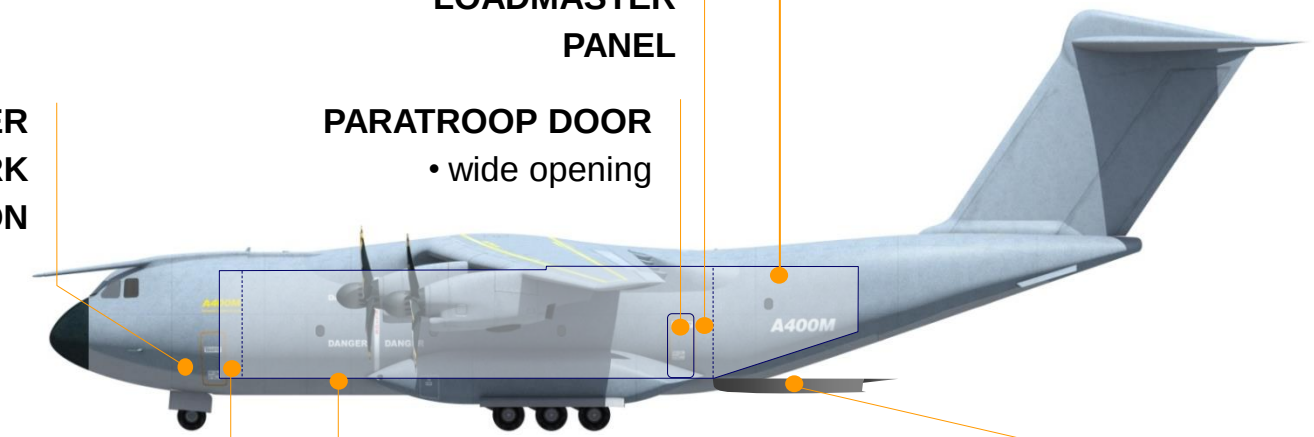
Impact (effect) of specific military requirements – Loads Handling (CHS)

POWER CRANE (optional)
- loading from ground level
- cross-loading

LOADMASTER PANEL

LOADMASTER WORK STATION

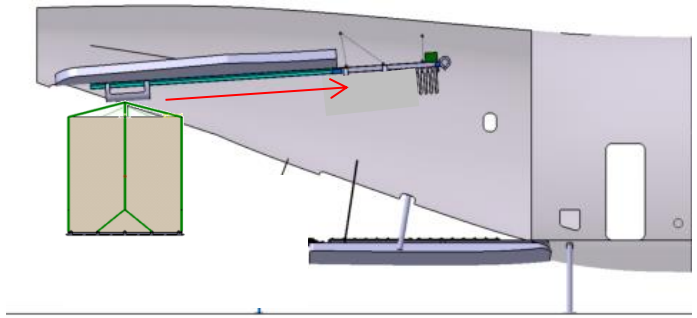
PARATROOP DOOR
- wide opening

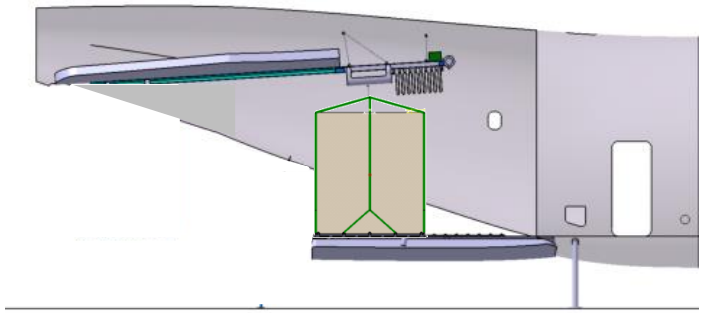


CARGO FLOOR
- retractable side rails and rollers
- tie-down rings
- In-flight reconfiguration
- accommodates civil and military pallets

POWERED WINCH

LOAD CARRYING RAMP
- same layout as cargo floor





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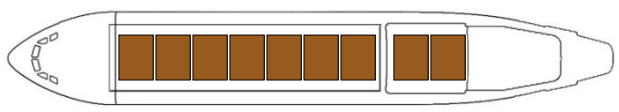
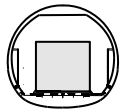
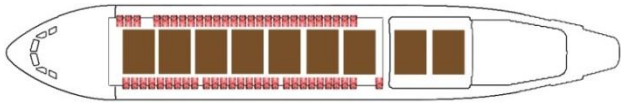
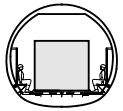
Impact (effect) of specific military requirements – Loads Handling (CHS)





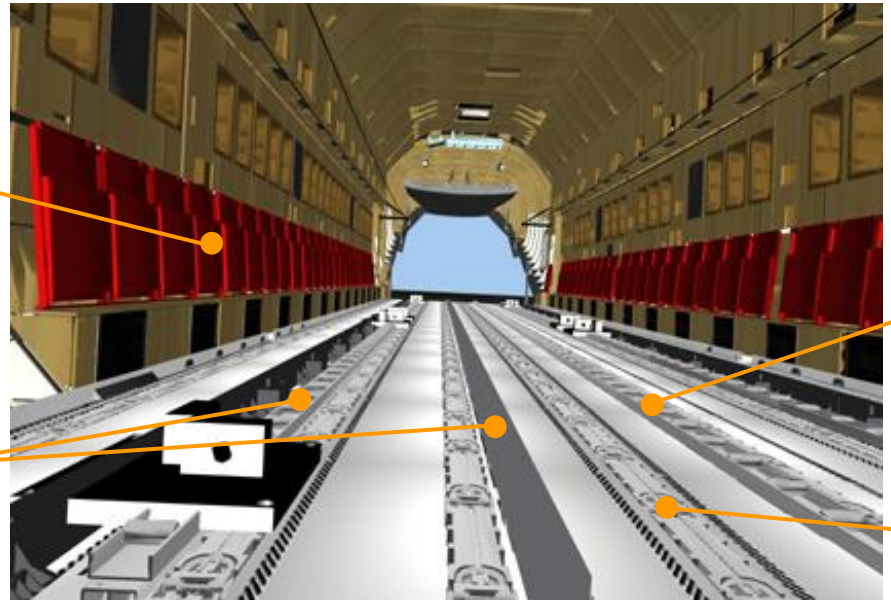
9 88”X108” pallets



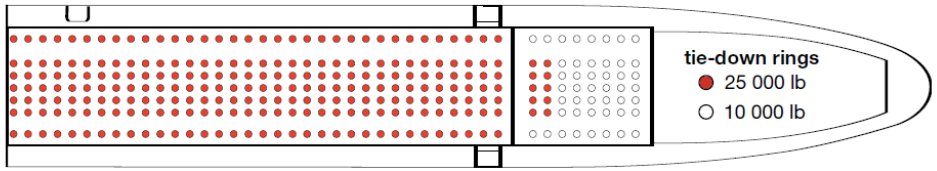


9 pallets and 54 troops

Foldable troop seats

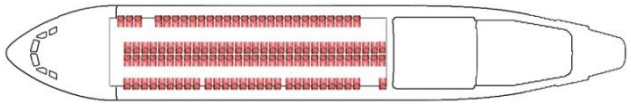


Roller-restraint system for standard military pallets

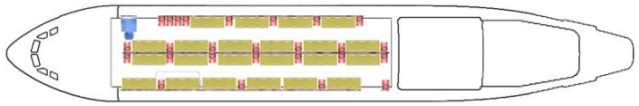


Roller-restraint system rotated to provide flat floor

Retractable tie-down rings



116 seats for troops and paratroops



66 stretchers & 25 medical attendants

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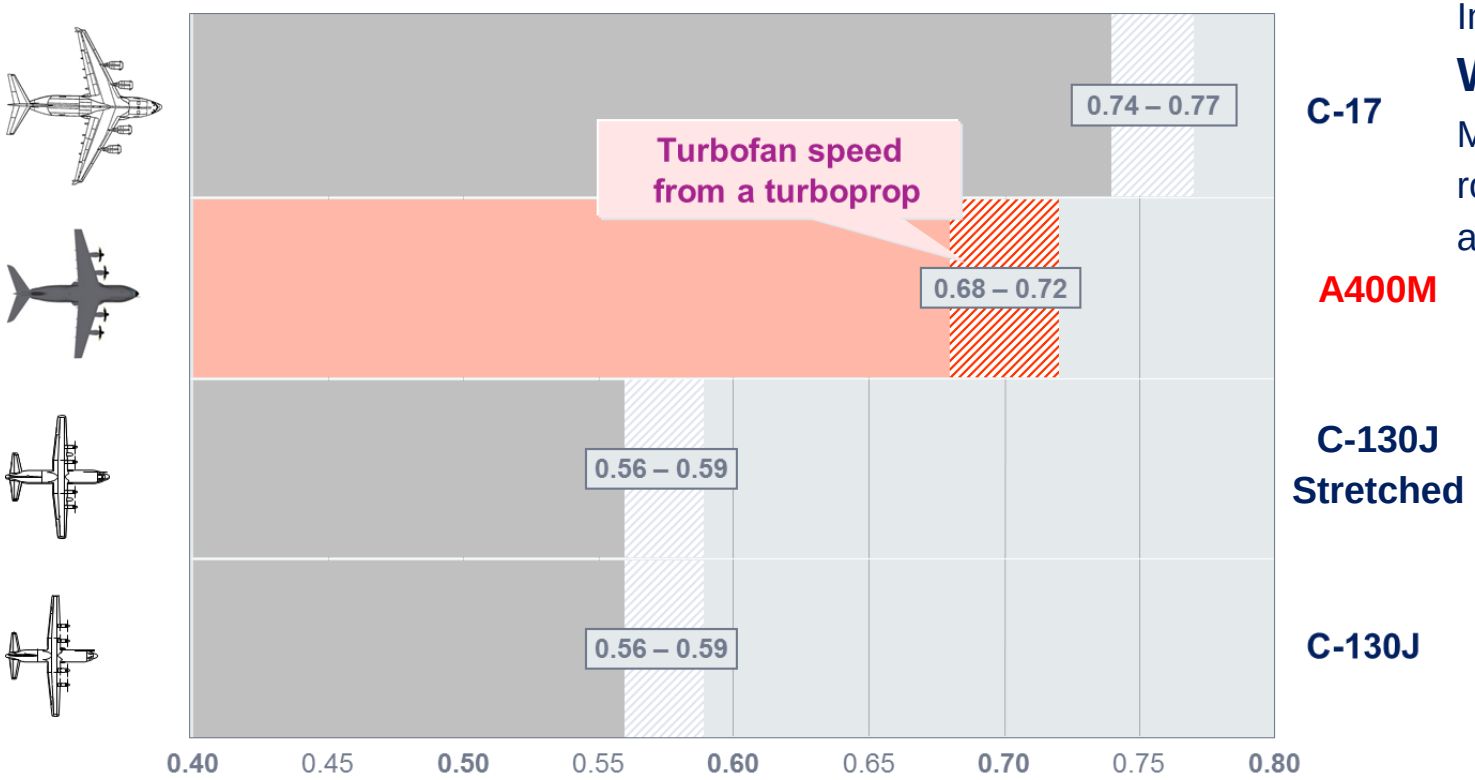
Impact (effect) of specific military requirements – Aerodynamics

Maximum Cruise Speed



Aero and speed requirements

Maximum and minimum speeds, Aerial Delivery speeds, Incidence angle for AD, simple High Lift devices

Wing design

Moderate 15º sweep wig, wing profile, no LE flaps, single rotation TE flaps, wing size and profile, wing setting angle, movable surfaces areas.

Prop Rotation: Down Between Engines

Symmetric airflow: Enhanced flight qualities and maneuverability. Effect on Stall Speed (Clmax). Minimizing vertical surface size

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Impact (effect) of specific military requirements – Structure

Low Level flight to minimize aircraft detection

Maximum speed 300kts, 50kts more than the one requested by civil regulations

That means a 44% more energy for the case of bird impact.

All surfaces suitable to receive a bird impact have to be reinforced

In general, the tactical maneuvers have a major impact on aero-loads envelope and structure design

Video

VTP Bird Impact Test (failed)

Example of wing bending tests on the full scale Static Test

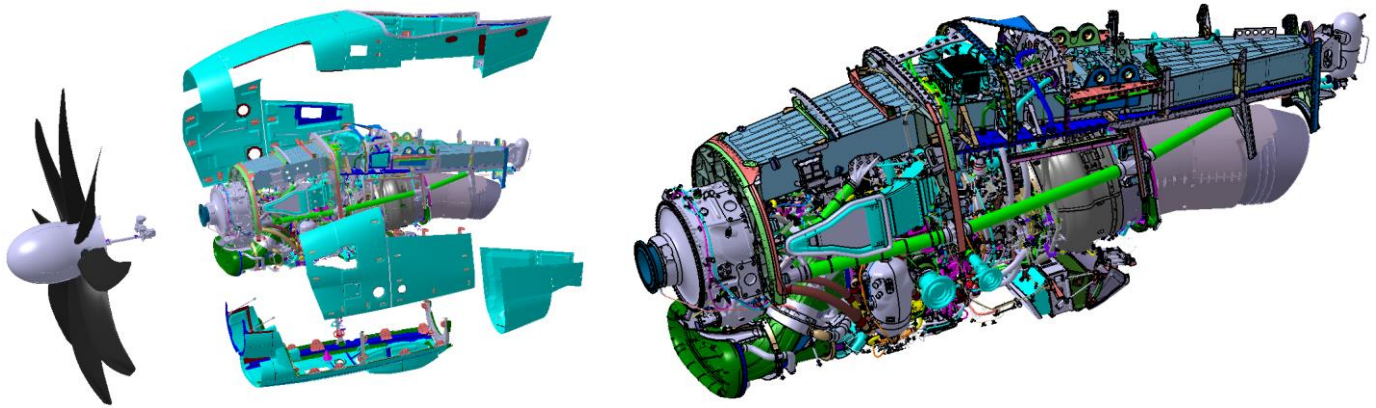
ES Wing Up
Bending J=1,5

Impact (effect) of specific military requirements – Power Plant

Power Plant selection: Turbo-propeller

Engine: EuroProp International TP 400-D6, Maximum Power: 11.000SHP
(Twice than the most powerful turboprop ever built in occidental countries)
Maximum Torque: 95.300 Nm

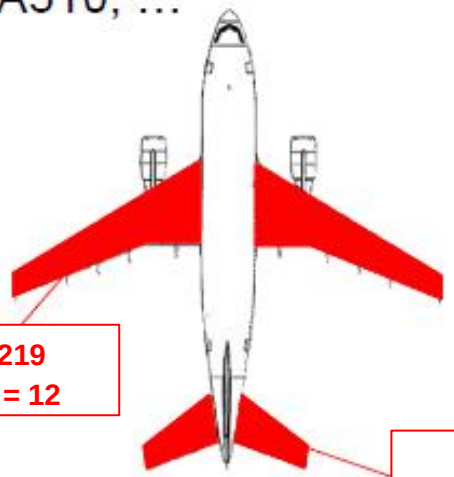
Propeller: RFHS FH386 - 8 blades, 5,33 m diameter
Operating range between 655 RPM to 860 RPM
Requirement for civil external noise certification: Counter rotatory propeller discarded



Impact (effect) of specific military requirements - Maneuverability and Flight Controls (1)

- A400M: the body of the A310, …

MTOW = 135 T



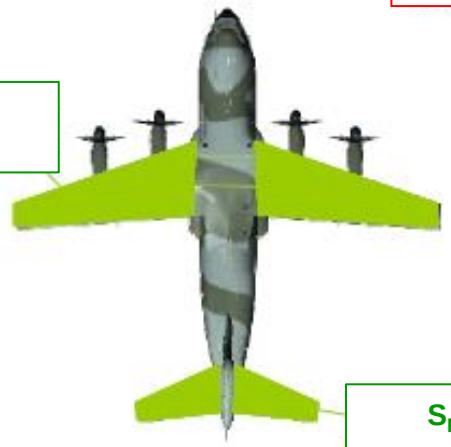
S_{REF} = 219
moving = 12

S_{REF} = 45
moving = 14

S_{REF} = 64
moving = 8

MTOW = 137 T

S_{REF} = 221
moving = 22



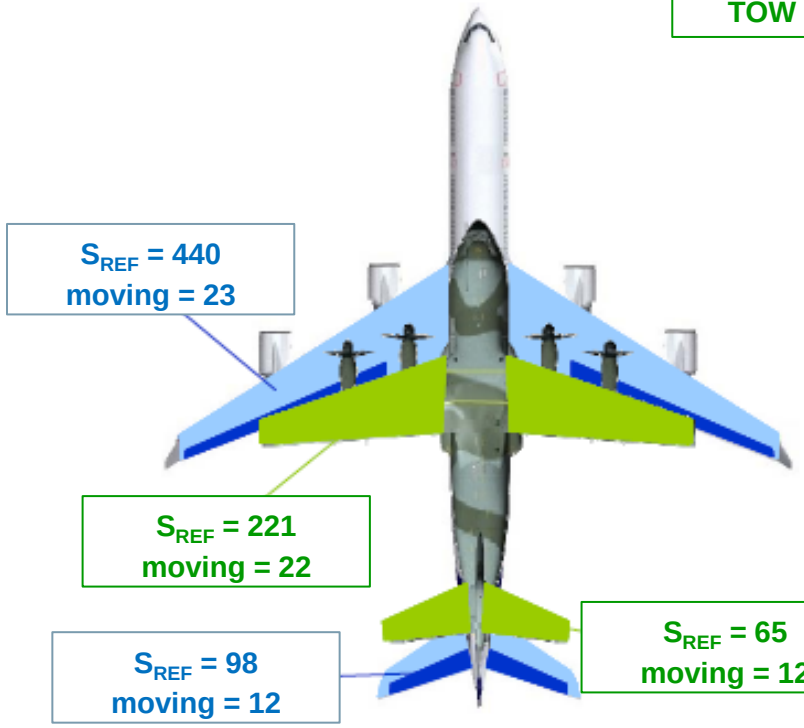
S_{REF} = 65
moving = 12

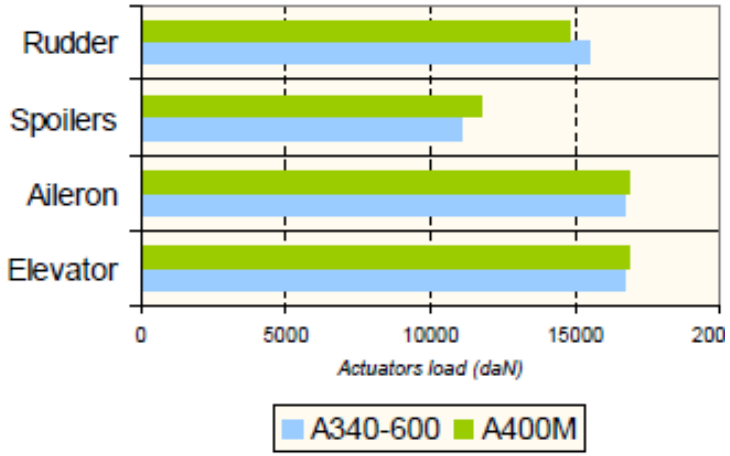
S_{REF} = 46
moving = 18

Impact (effect) of specific military requirements - Maneuverability and Flight Controls (2)

- …., but the muscles of the A340-600

TOW = 137 T





HIGH MANEUVERABILITY

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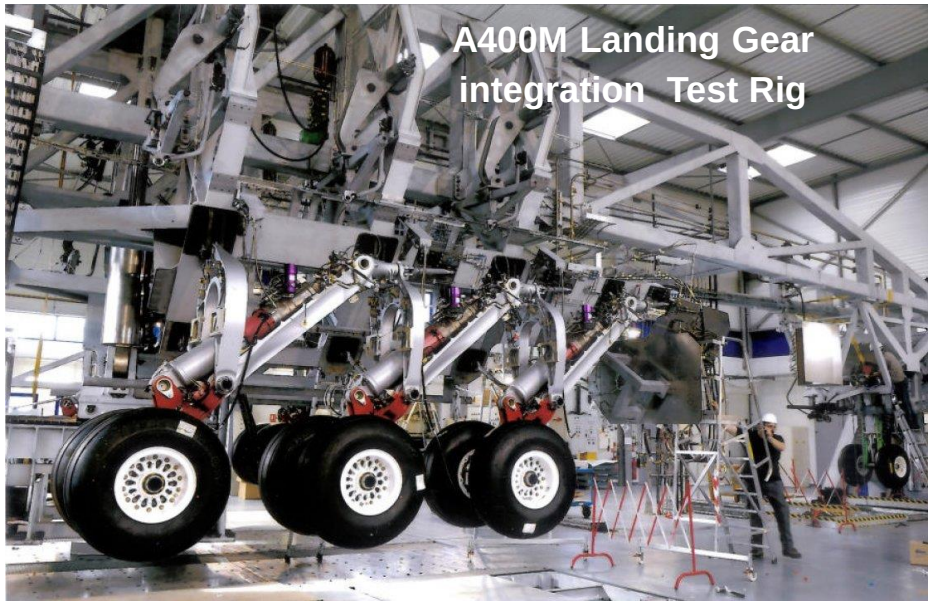
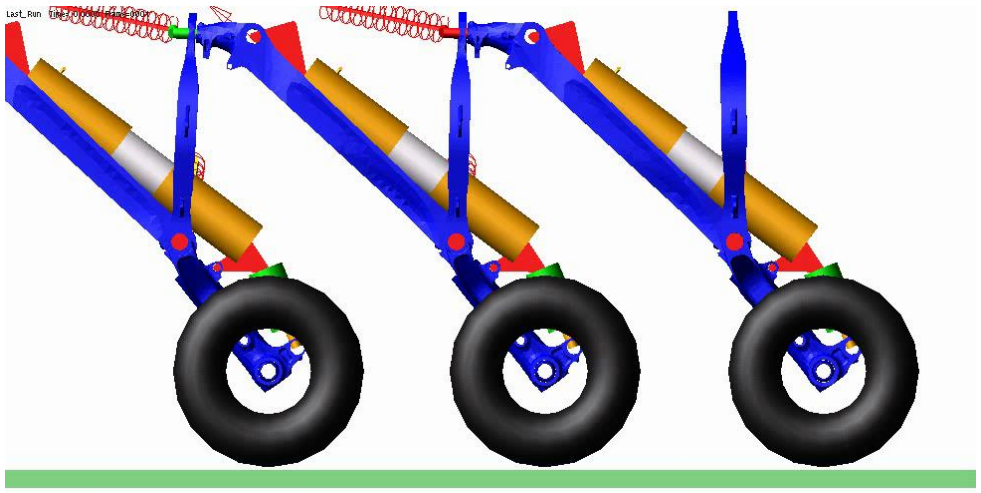
Impact (effect) of specific military requirements – Landing Gear

- High sink rate for tactical landing (12 fps) which is only 20% more than civil regulations requirements but means a 44% more kinetic energy to be absorbed by the LG
- That requires shock absorbers with long displacement and high energy absorption.
- High Dynamic Landing Loads
- Significant parts of the wing and fuselage are dimensioned by such dynamic loads.
- Operation on unpaved runways with bumps and obstacles lead to a solution of Double Chamber Shock Absorbers.





Validation of LG design with free fall tests on a LG Rig

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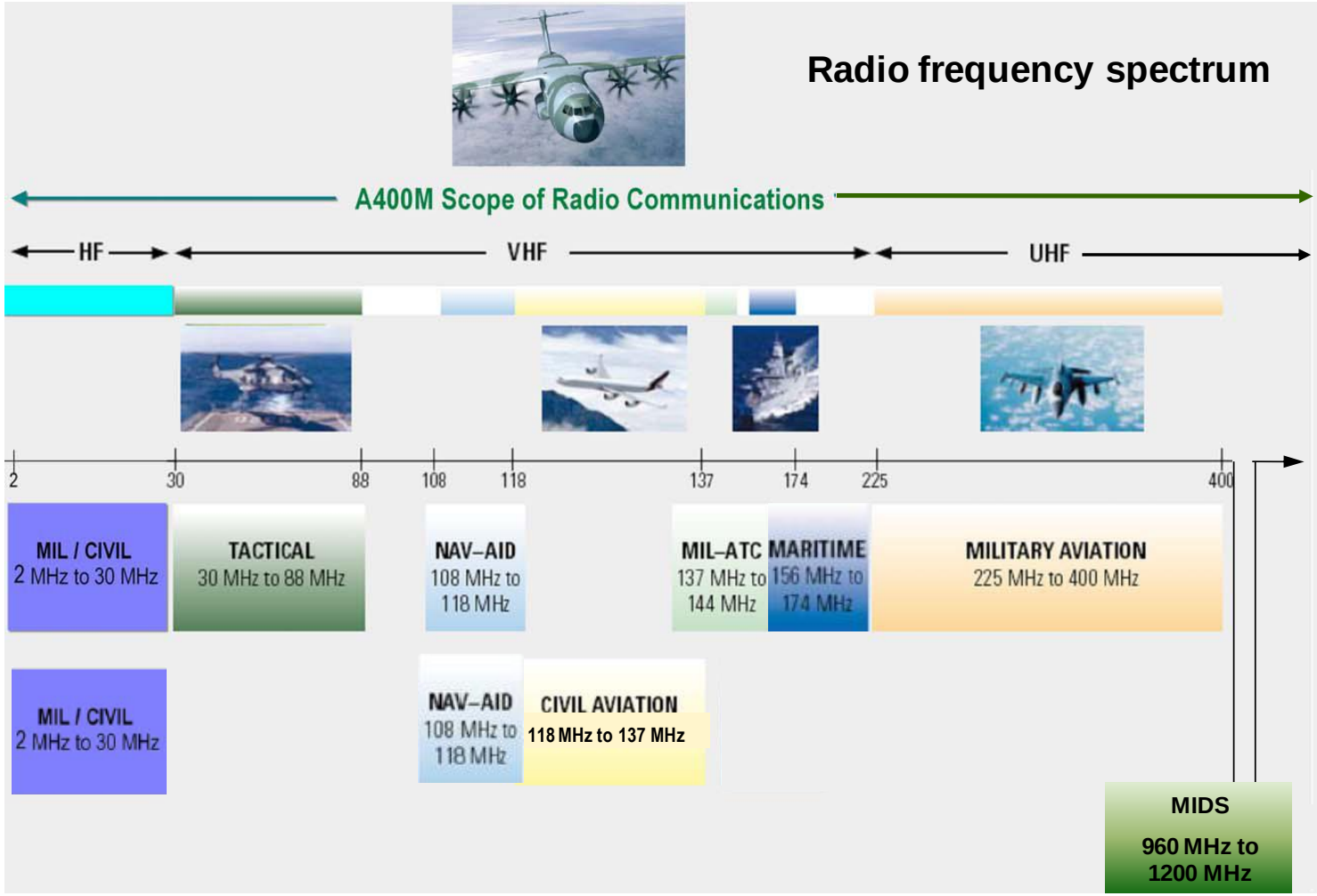
Impact (effect) of specific military requirements – Communications to cover civil & military frequency ranges

Specific military requirements:

- 4 multiband V/UHF radios + 2 military HF radios
- IFF civil and military function + DF
- Wireless Intercom system in cockpit and cargo cabin
- COMSEC, Encryption, agile frequency changes and quick data erasure.
- SATCOM
- MIDS (Tactical Data Link/Link 16).



Impact (effect) of specific military requirements – DASS

Defensive Aids Sub System (DASS): Flexible and modular includes optional equipment:

- DASS computer with auto-mode.
- Radar Warning Receiver
- Missile Warning Systems
- Expendables Dispensing System
- Future developments:
  - Direct Energy Infra-Red Counter Measures (DIRCM)
  - Laser Warning Receiver
  - Towed Radar Decoy

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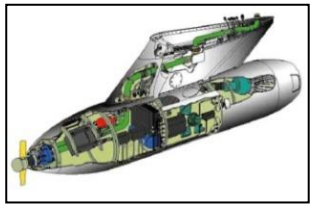
Impact (effect) of specific military requirements – AAR

BASIC
WING POD PROVISION
Fuel connections,
wiring, vents & drains

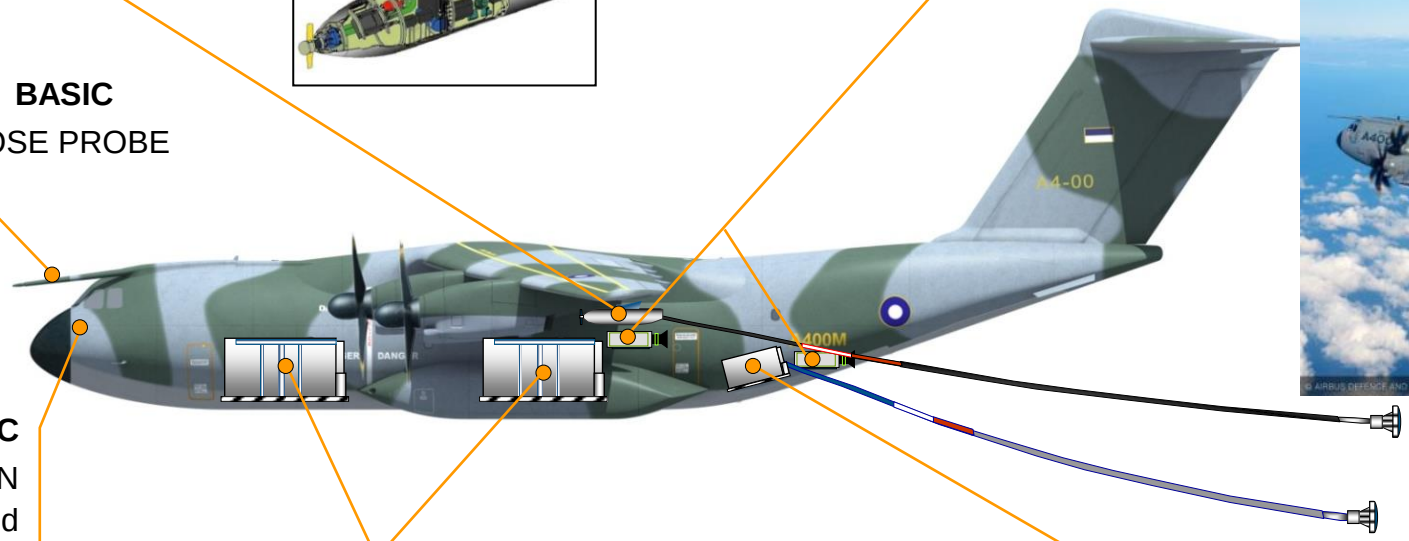
OPTIONAL
HOSE & DROGUE WING PODS



BASIC
VIDEO SYSTEM
PROVISION
Fittings & wiring

OPTIONAL
VIDEO CAMERAS (3)
and ASSOCIATED COMPUTER

BASIC
NOSE PROBE



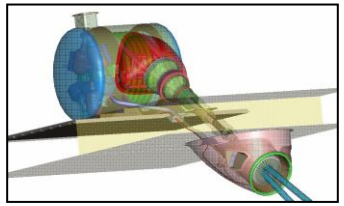
BASIC
AAR PROVISION
Cockpit Controls and
Fuel Management System

OPTIONAL
CARGO HOLD TANK
PROVISION
Fuel connections,
wiring, vents & drains

OPTIONAL
CARGO HOLD TANKS

OPTIONAL
HDU PROVISION
Fuel connections,
wiring, vents & drains,
ramp/door adaptor

OPTIONAL
HOSE & DROGUE UNIT



AIRBUS

QUESTIONS?

THANK YOU