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3. General Definition

3.1. Physical MockUp (PMU)

The mockup is traditionally a physical model of a component, assembly, or entire product. *It can be full-size or a scale model and made of paper,* wood, *metal* or actual production hardware.
The **PMU** is a design and manufacturing tool used for:

- *space allocations*
- detail part fitment check
- assembly verification
- interference and clearance studies
- *background structure for tubes, hoses, ducts and wire routing*
- determination of electrical wiring harness length
- part installation and removal
- reliability and maintenance studies

The disadvantages of a **PMU** are as follows:

- expensive to be modified or duplicated
- requires floor space, materials and tools
- slow responce to changes
- inability to reflect real time configurations

3.2. Electronic MockUp (EMU)

The **EMU** is a computerized model of a component, assembly, or entire product.
It uses a three dimensional **CAD** system to fulfil the physical mock up requirements by assembling all data coming from different departments or companies to a digital dataset.
The **EMU** is a digital master tool for parts assembly, space allocation, development of system routings and fitment check of parts.

The major advantages of using the **EMU** are as follows:

- availability of mock up early in the design phase
- availability of the same mock up status (master) at all four partners
- the **EMU** representing the latest design status throughout the design phase
- transparency of the actual design status
- first step of "concurrent engineering"
- continuous check of fitment and function from the beginning of the design
- reduction of design errors

3.3. Categories of EMU types according MIL M 86500

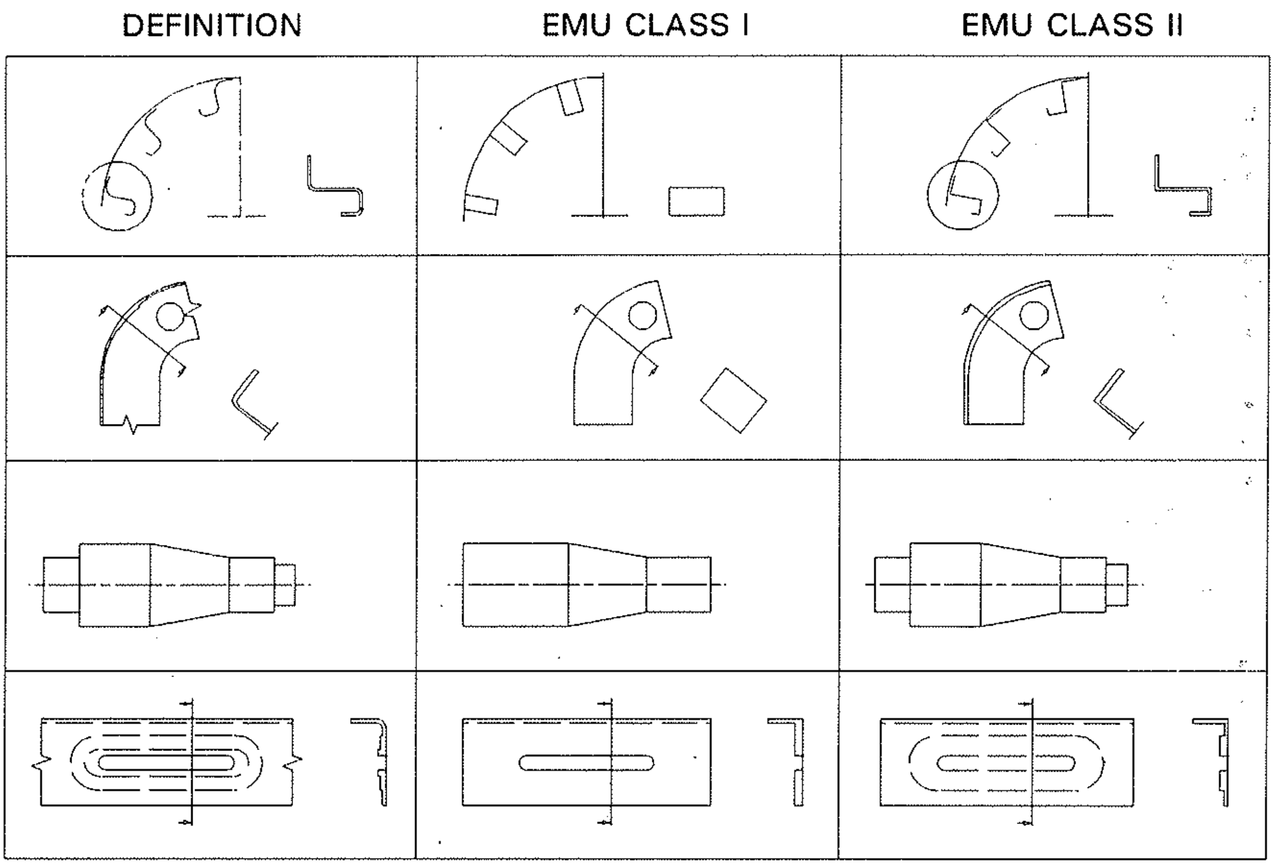


Figure 03: Comparison between mockup classes according MIL M 86500

3.3.1. Class I MockUp

Used in pre design phase to determine shape, to allocate space
or to present new idea in form of envelopes.

Therefore the geometry is proportionally but not necessarily dimensionally accurate.

3.3.2. Class II MockUp

Used in detail design and as a demonstrator.

Constructed with overall dimensions as close to drawing as practical.

Tolerances of dimensions according ISO 2768 sg (DIN 7168 sg).

4. Methodology and MockUp Philosophy

4.1. General

Before starting the preliminary design work the partner companies decided to use **CATIA** as graphic design tool for the whole **NH90** program.
The prerequisite for the common use of **CATIA** in the **NH90** program at the partner companies was to harmonize the general method of working with the system, the data exchange procedures, and especially the methodology of the **EMU**.

4.2. CATIA Project File and Start model

Basis for a efficient application of a **EMU** at all partners was the harmonisation of the Release, model size, project file and the definition of a common NH90 start model.

CATIA release for NH90 applications:	V3 R2 MR3
DATA SIZE:	1.7 MB
INDEX SIZE:	0.3 MB

The project file contains all general base information concerning model standards, plot sizes, line types, piping end types, layer descriptions, patterns, colors and attributes.

The start model gives each designer the possibility to work with a prestructured well known model for easy application in the **EMU**.
The start model defines the model identifier, model standards, color standards, layer reservations, filters, text and dimension standards and the reporter function.

4.3. Model Rules

Following rules are the base for the utilisation of the **EMU**:

- All Products are defined completely in **3D** in the assembled position in the datum axis system.
- Each model contains one datum axis system (*AXS1).
- The datum axis system is not allowed to be transferred, renamed ore deleted by the user.
- Other necessary axis systems can be created by the user but these axis systems have to have a reference to the datum axis system (e.g. often used parts)
- The major geometry of products contained to the SPACE model have to be represented in the form of **CATIA SOLID's**.

For memory saving all designers are forced to calculate ***Line approximation and SAG****-Value of* **SOLID** parts according following rule:

LINEAPP:	*Line approximation (number of lines per quadrant)*
SAG:	*accuracy (distance between radius and secant)*
rk	*curvature radius*

$$LINEAPP = \frac{45}{a\cos(1 - \frac{SAG}{r_k})} \qquad SAG = r_k \cdot (1 - \cos(\frac{45}{LINEAPP}))$$

Figure 04: Term for Line approximation and SAG value

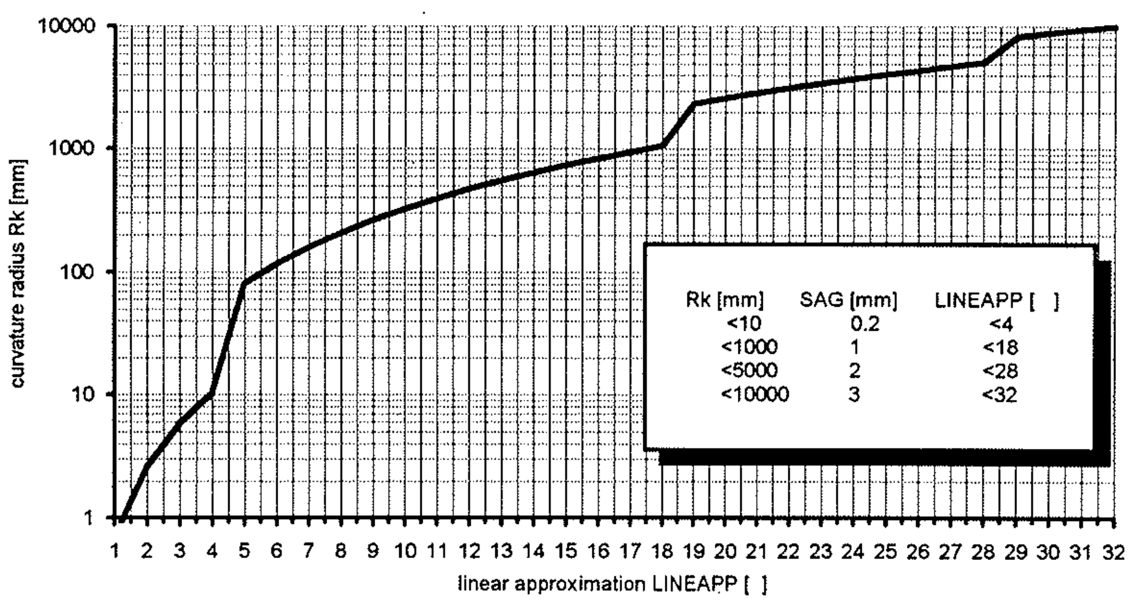


Figure 05: Accuracy of SOLID's respect to curvature radius

4.4. Helicopter Zoning

The **NH90** zoning is based on the **AECMA** specification **1000D**.
The zones are characterized by **3** digit number combinations. The requirement having the zoning information as a part of the model identifier leads to a additional **2** digit number combination. A correspondence table between both systems is fixed in the **NH90** Helicopter Standard **HS121**.

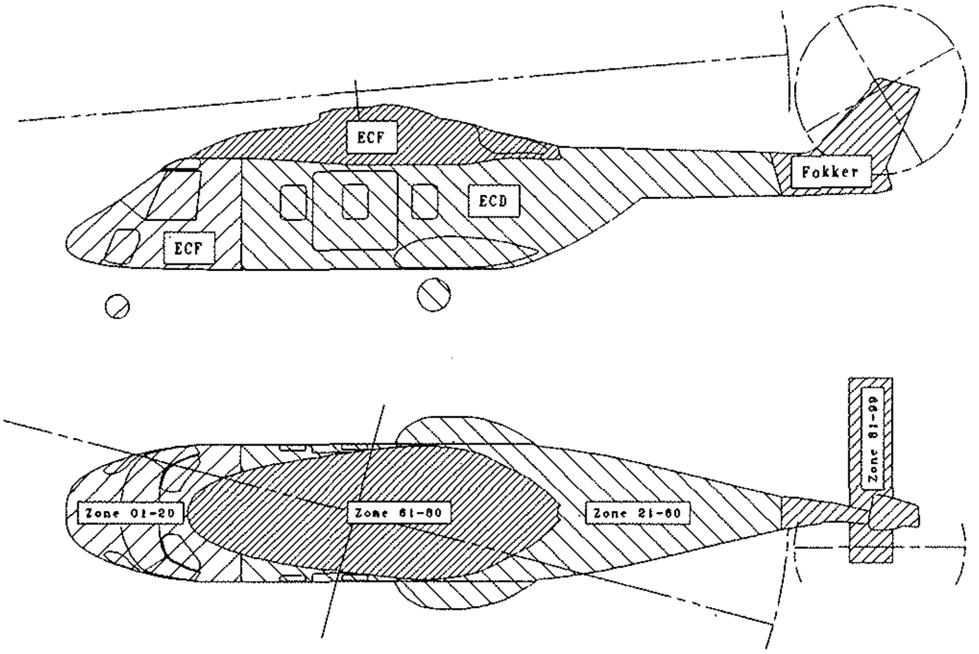


Figure 06: NH90 Zoning according HS121

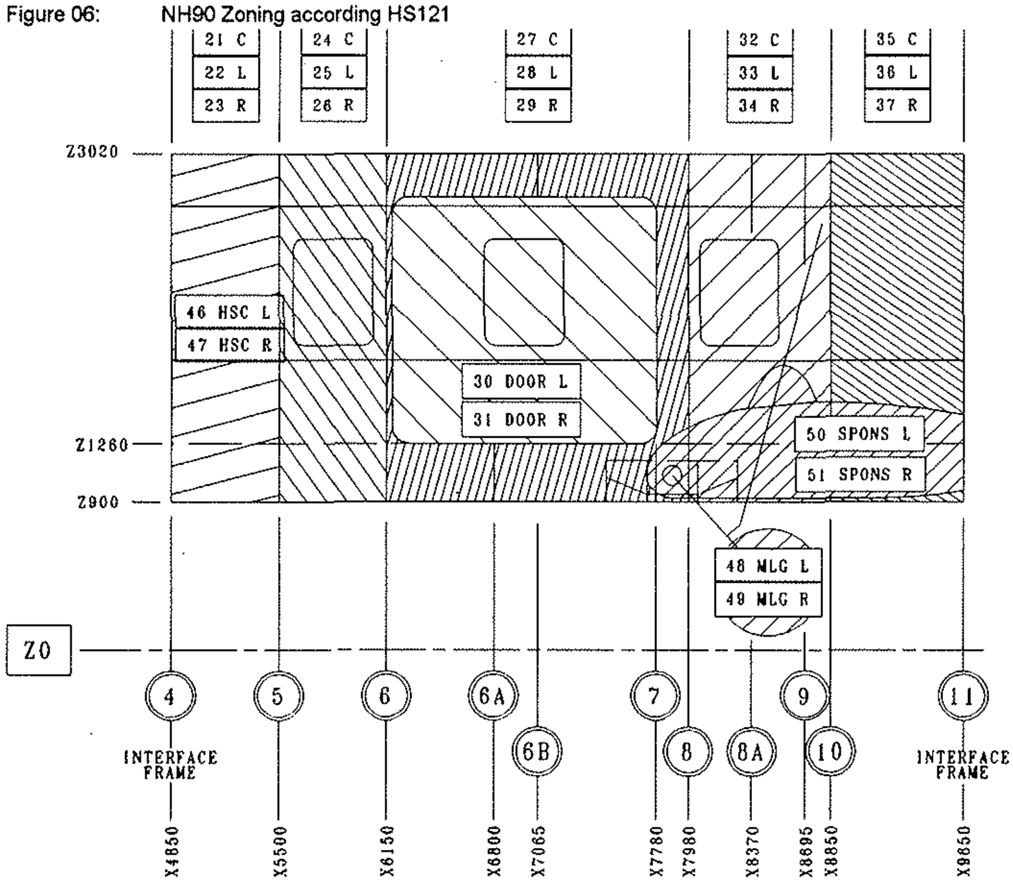


Figure 07: Zoning Center Fuselage

4.5. EMU Model Identifier

In the **NH90** program the four partner companies decided to have common **CATIA** model identification.

1 - 12	13	14 - 15	16	17 - 18	19	20	21 - 53	54	55 - 61	62	63 - 65	66 - 70
Part ID (according ATA 100)		**Index**		**Overlay. Nr.**	**Module**		**Title (Digit 21 - 32) + Zoning (Blocks) (Digit 33 - 53) (max 7 Blocks)**		**Prototype validity**		**Type of Subsystem**	**Datatransfer or Comment**
N533C1234567		*A1*		*00*	*C*		*Side Shell left B21B22B23B24B25*		*123NNNN*		*STR*	*TOMAR*

Abbreviations for EMU Partner Designation (Digit 5):

ECF	***B***
ECD	***C***
Agusta	***P***
Fokker	***S***

Abbreviations for Modules (Digit 19):

Master	***M***
Cockpit	***P***
Center Fuselage	***C***
Rear Fuselage	***R***
Upper Deck	***U***
Tail Group	***T***

Abbreviations for Type of Subsystem (Digit 63 - 65):

All Subsystems	***ALL***		
Loft	***LOF***	*Fuel System*	***FUS***
Structure	***STR***	*Equipment*	***EQT***
Controlling	***CON***	*Hydraulic*	***HYD***
Transmission	***TRN***	*Electric*	***ELT***
Rotor	***ROT***	*Avionic*	***AVI***

Abbreviations for Comment (Digit 66 - 70):

erase	***#@***
depot	***#D***
rework	***#R***
not valid	***#X***

Abbreviations for Zoning (Digit 33 - 53):

Blocks	***see N063C1001101***
all Zones	***MAS***
Cockpit	***COC***
Center Fuselage	***CFS***
Rear Fuselage	***RFS***
Upper Deck	***UPD***
Tail Group	***TAI***

Abbreviations for Data Transfer (Digit 66 - 70):

NH90 Partner	***TOPAR***
ECF Marignane	***TOMAR***
Agusta	***TOAGU***
Fokker	***TOFOK***
Donauwörth	***TODON***
Ottobrunn	***TOOTN***

Abbreviations for PT validity (Digit 55 - 61):

PT1	***1NNNNNN***
PT2	***N2NNNNN***
PT3	***NN3NNNN***
PT4	***NNN4NNN***
PT5	***NNNN5NN***
PT1 - PT3	***123NNNN***
PT2 - PT4	***N234NNN***
PT3 - PT5	***NN345NN***

Figure 08: EMU Model Identifier

4.6. EMU Subsystem / Geometry Organisation

Following table shows the **CATIA** layer organisation applied in the **NH90** program.

	LAYER	System Geometry	Wire Frame	SURFACE	FACE	VOLUME	SOL, POL, PIP	DETAIL	not defined Geometry	FREE
AXIS	0									
WORK	1 - 29									
DRAFT	30 - 49	30 GEOMETRY	31 DIM, TXT	32 DET, LIB, SYMB						33 - 49 DRAFT FREE
Loft	50 - 59	50	51	52	53	54	55	56	57	58 - 59
Structure	60 - 69	60	61	62	63	64	65	66	67	68 - 69
Controls	70 - 79	70	71	72	73	74	75	76	77	78 -79
Transmission	80 - 89	80	81	82	83	84	85	86	87	88 - 89
Rotor	90 - 99	90	91	92	93	94	95	96	97	98 - 99
Fuel System	100 - 109	100	101	102	103	104	105	106	107	108 - 109
Equipment	110 - 119	110	111	112	113	114	115	116	117	118 - 119
Hydraulic	120 - 129	120	121	122	123	124	125	126	127	128 - 129
Electric	130 - 139	130	131	132	133	134	135	136	137	138 - 139
Avionic	140 - 149	140	141	142	143	144	145	146	147	148 - 149
Tooling	150 - 159	150	151	152	153	154	155	156	157	158 - 159
Phantom Geometry	160 - 169	160	161	162	163	164	165	166	167	168 - 169
FREE	170 - 249									
SYSTEMS	250 - 254	250 DRAFT FRAME	251 SPACE FRAME	252 reserved	253 reserved	254 NO PLOT				

Figure 9: Layer organisation in the NH90 Program

4.7. Supporting Programs

Working efficiently under **CATIA V3R2MR3** several supporting programs **(IUA** = *Interactive User Access* macros) have been developed at **ECD**.

- **/M CATOVER**
  gives the possibility under **CATIA** V3R2MR3 to store a overlay in a **#PARENT** model.

- **/M ECDLAY**
  Transfer of different **CATIA** geometry to several **CATIA** system layers by selecting a basis layer in a panel. (Ref.: Figure 9)

- **/M ECDNAM**
  Helps the designer to store the **CATIA** model with a correct model identifier. (Ref.: Figure 8)

- **/M ECDATT**
  Transfer of all relevant information of the member name to attributes linked at the datum axis system.

- **/M SAGLIN**
  Helps the SOLID designer to find the correct values for linear approximation LINEAPP and SAG. (Ref.: Figure 4, 5)

- **/M ECDSTART**
  recall of ECD start model

- **/M ECDCOL**
  Adapting of the **CATIA** color tables to the ECD standard

- **/M ECDREAD**
  gives the designer the possibility to look for prototype validity, zones, subsystems and general search strings the **EMU** file with a following automatically overlay creation.

5. Application of EMU in the NH90 Program

5.1. General

A prerequisite to **EMU** is a **100% 3D** digital product definition of all parts in **CATIA SOLID** format. This requirement necessitated the need for a complete different design protocol from former product definitions.
Each designer has to use the common **NH90** start model before defining a new part or assembly. In this first step there are no other rules in the way of working with **CATIA**. Before releasing a predesign or official issue of the finished part the **CATIA** model has to conform with several rules like layer organisation, colors and model identification. This **CATIA** model standardisation can be done by each designer automatically with help of several **IUA** macros. (Ref.: Chapter 4.7)

5.2. EMU Responsibility Share

A common understanding of the EMU responsibility share leads to a time saving and efficient design process. (Ref.: Modules Fig.01)

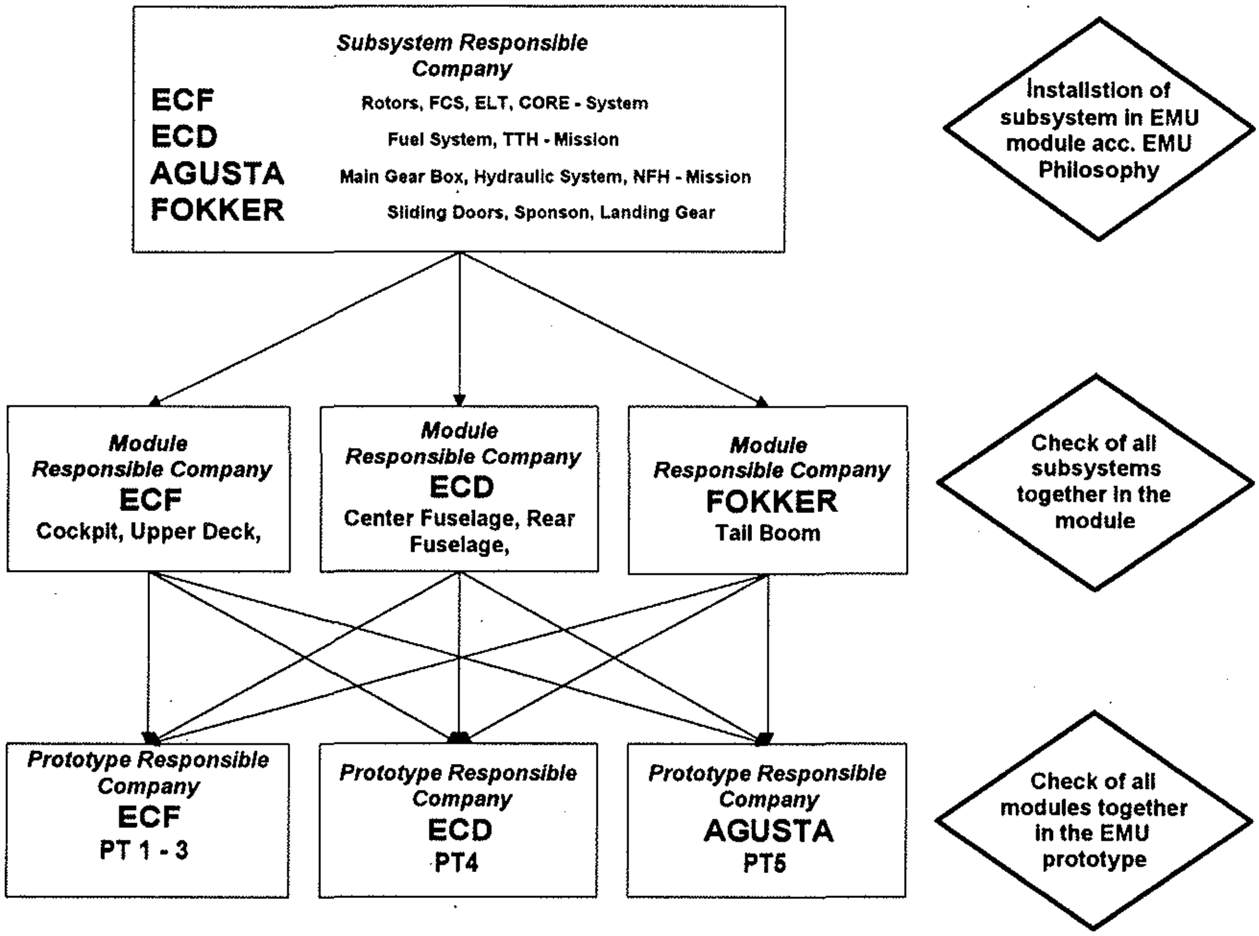


Figure 10: EMU Responsibility flow

5.3. Area Manager

The following tasks have to be taken over by the area manager:

- receive the **SOLID** entities of the released models
- control and manage configuration of the **EMU**
- build digital mockup installations in the helicopter zones and check for interferences
- provide feedback to engineering department for design updates
- approve **EMU** release

The area manger enables each designer always to use actual **NH90 EMU** data.

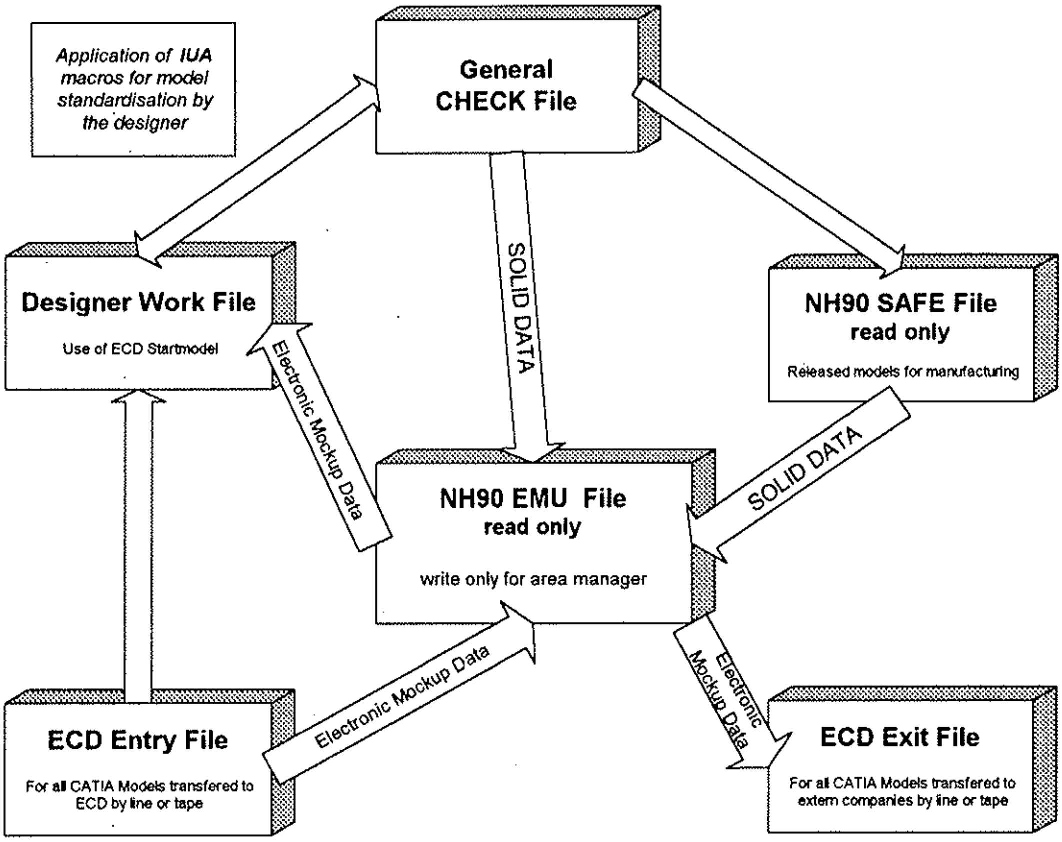


Figure 11: Data flow during Integration process at ECD

Due to **CATIA** limitations in model size, number of overlays and screen buffer size most of the **EMU** database consist of subsystem assembly models located in their helicopter zone.

5.4. Update of Electronic MockUp Data

NH90 partner companies decided as an internal solution to have a monthly update of all **EMU** relevant **CATIA** data.

ECF/ECD	ECF/AGUSTA	ECF/FOKKER	ECD/AGUSTA	ECD/FOKKER	FOKKER/AGUSTA
on-line	tape	tape	tape	tape	tape

Figure 12: Datatransfer between NH90 partner companies

Using the INTERNET in future encrypted data transfer will be easier and provide cost and time savings.

5.5. Space Allocation in the Electronic MockUp

In concurrent design, development of helicopter subsystems as well as structures are occurring simultaneously.

This initial design activity is referred to as space allocation, during which all disciplines are fighting for space within the helicopter.

Solid geometry, as it is generated, is submitted to a shared **EMU** file system where the area manager checks for part interferences ant tracks the status of identified interferences to guarantee their resolution.

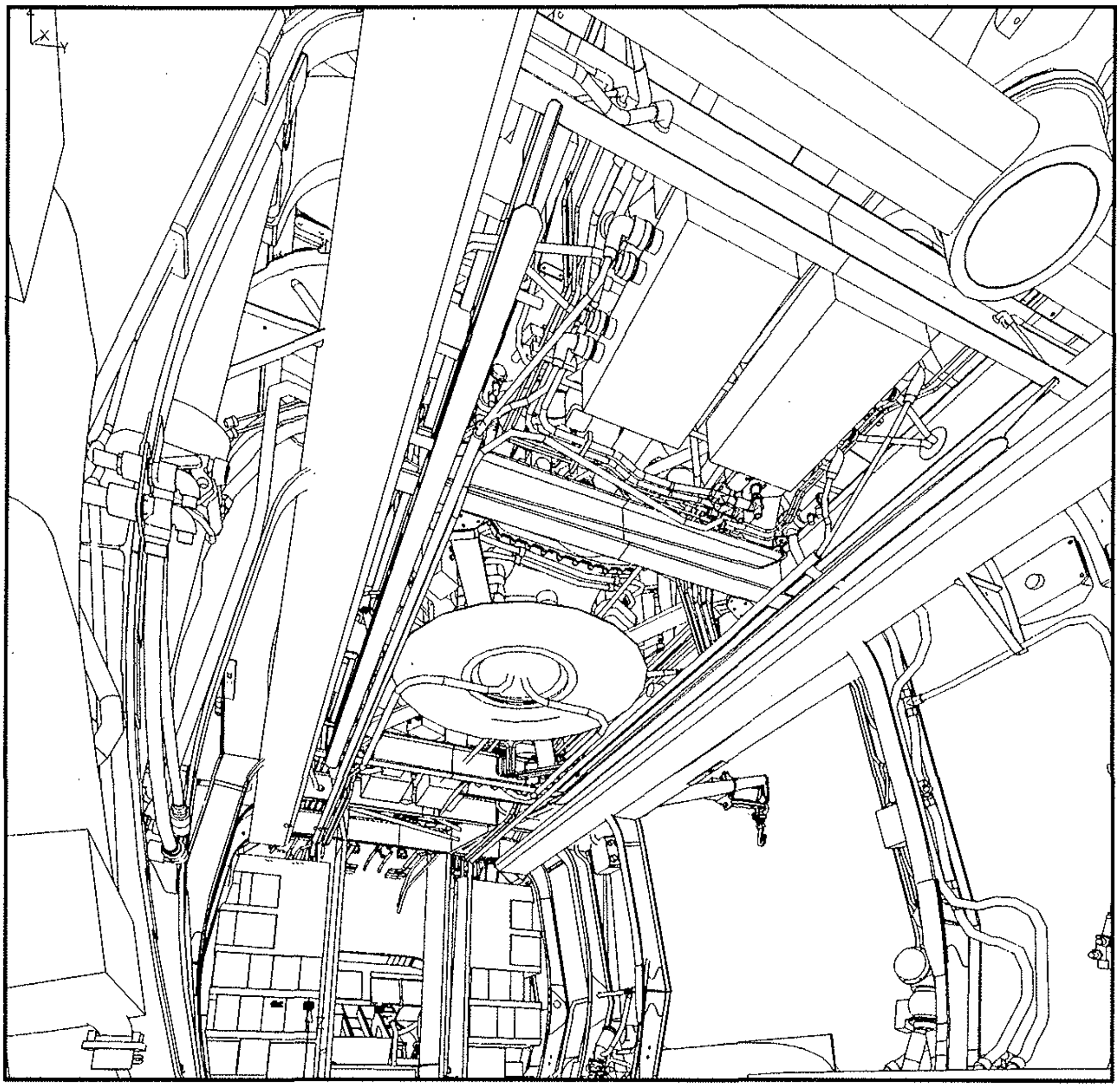
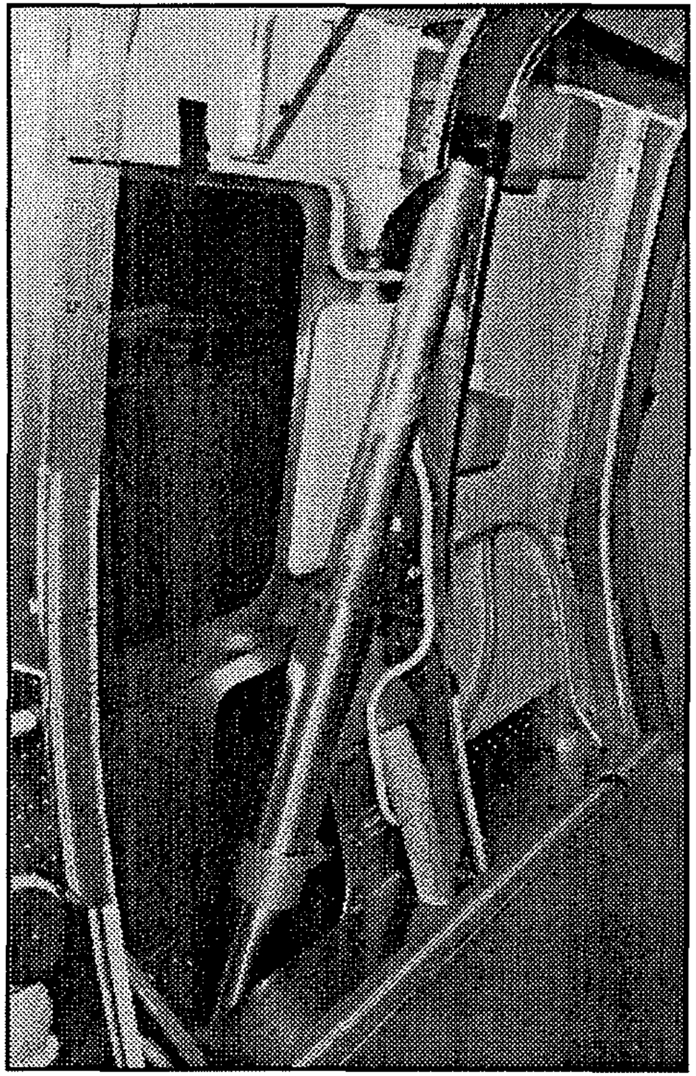


Figure 13: View inside Electronic Mockup TTH (PT4)

5.6. Comparison between Physical and Electronic MockUp



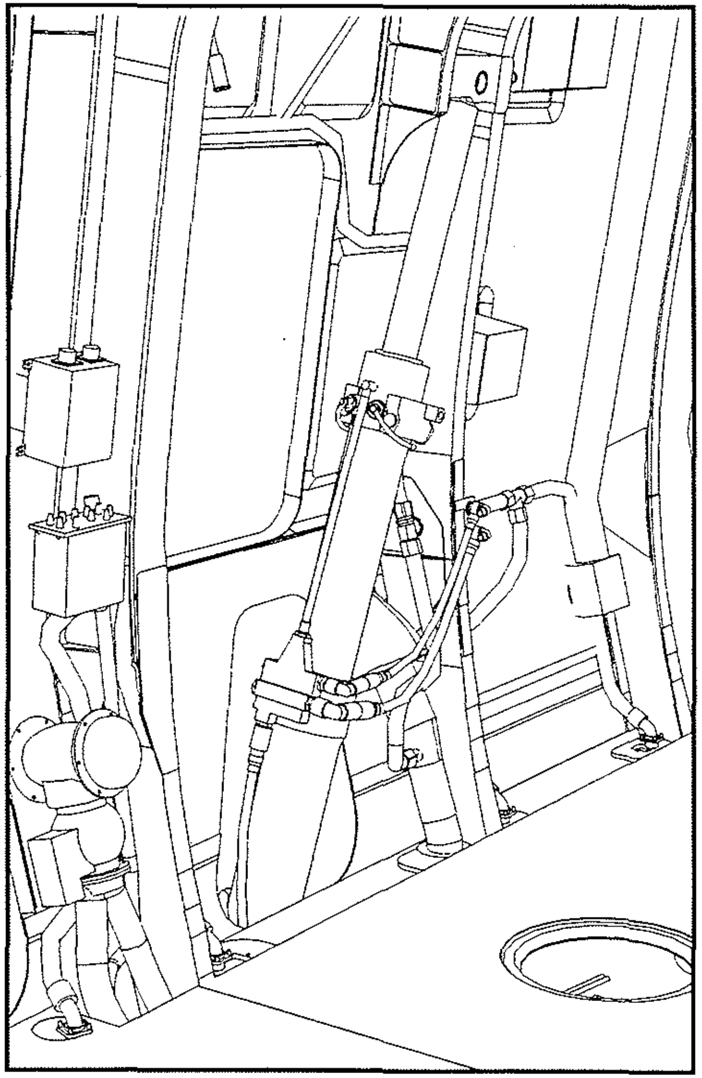


Figure 14 compare a zone of the **EMU** to its physical Class I counter part.
The use of the **EMU** gives the designer the opportunity to check detail product definition in **3D** such as points, lines curves, surfaces and solids, thus virtually eliminating downstream interpretational errors.

The ability to concurrently develop the system routing along with the structural definition eliminates the human errors associated with managing a physical mockup.

Using the concurrent product definition approach, the electronic database is continually updated to reflect the most concurrent engineering definition.
Feedback loops with physical mockup data is eliminated.

Figure 14: Comparison between PMU and EMU

5.7. Interference Checking

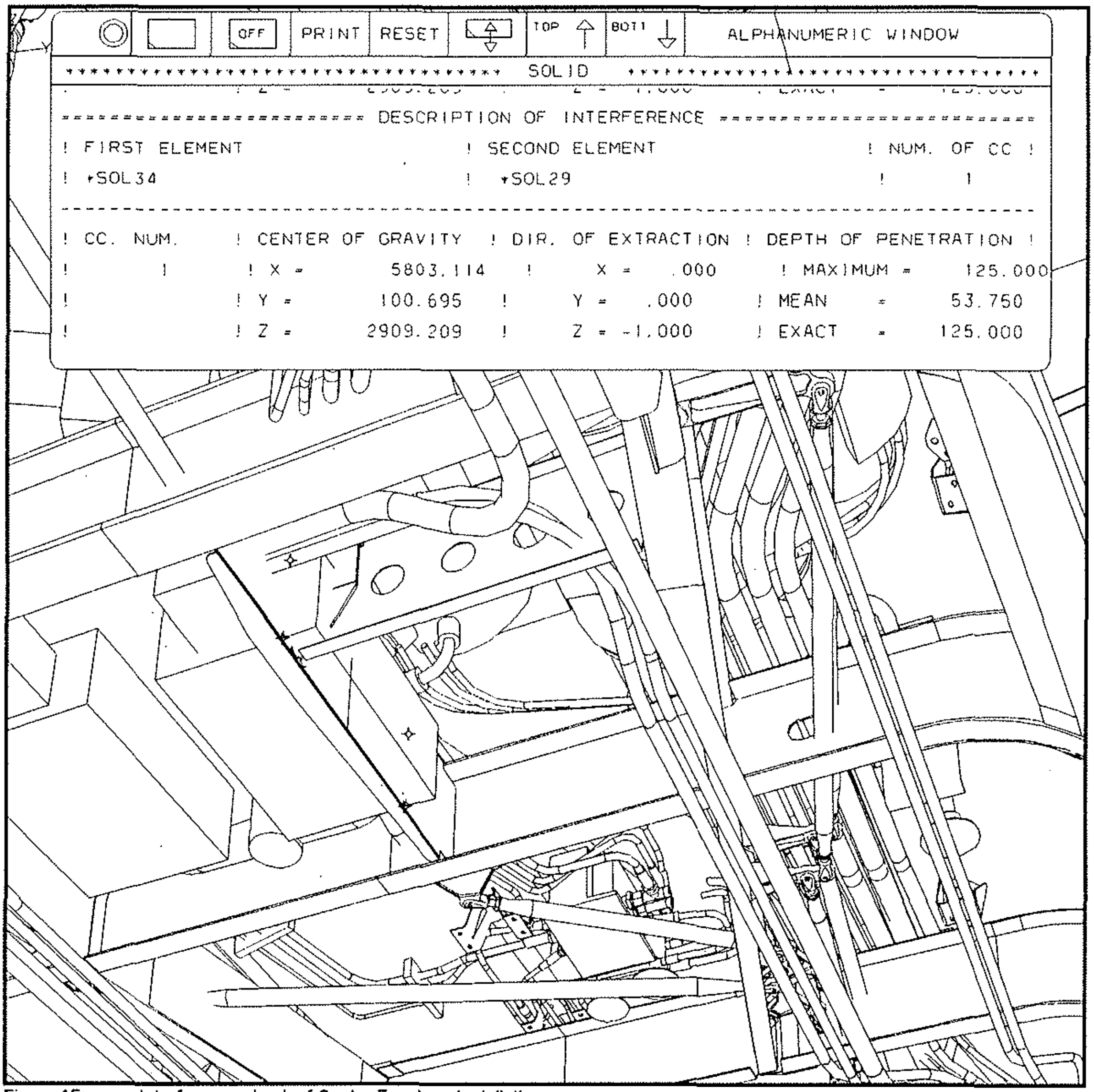
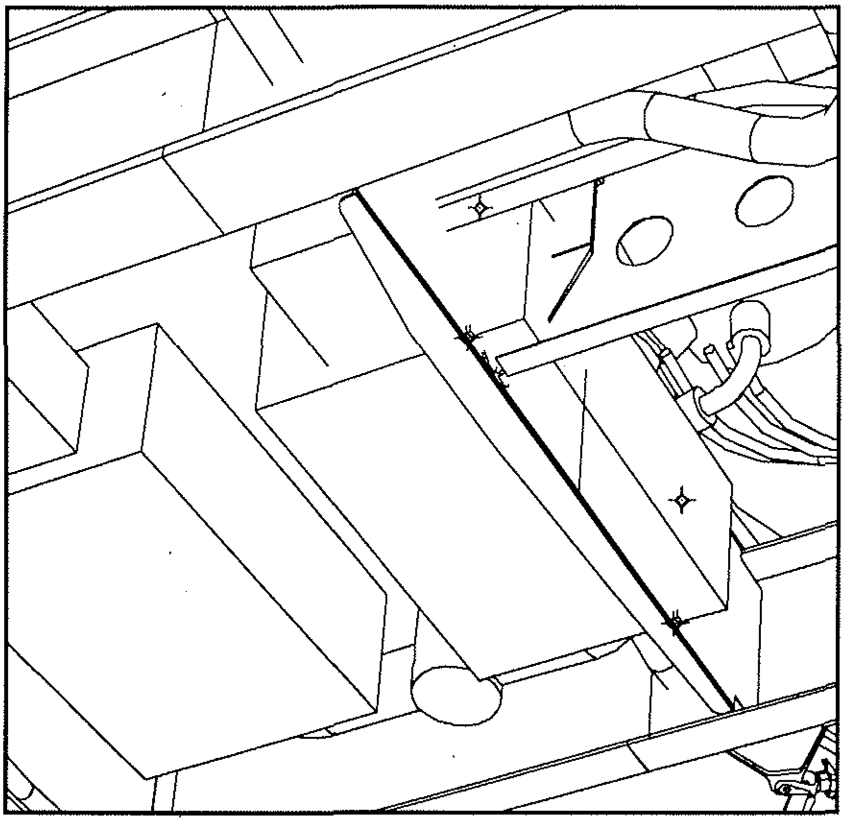


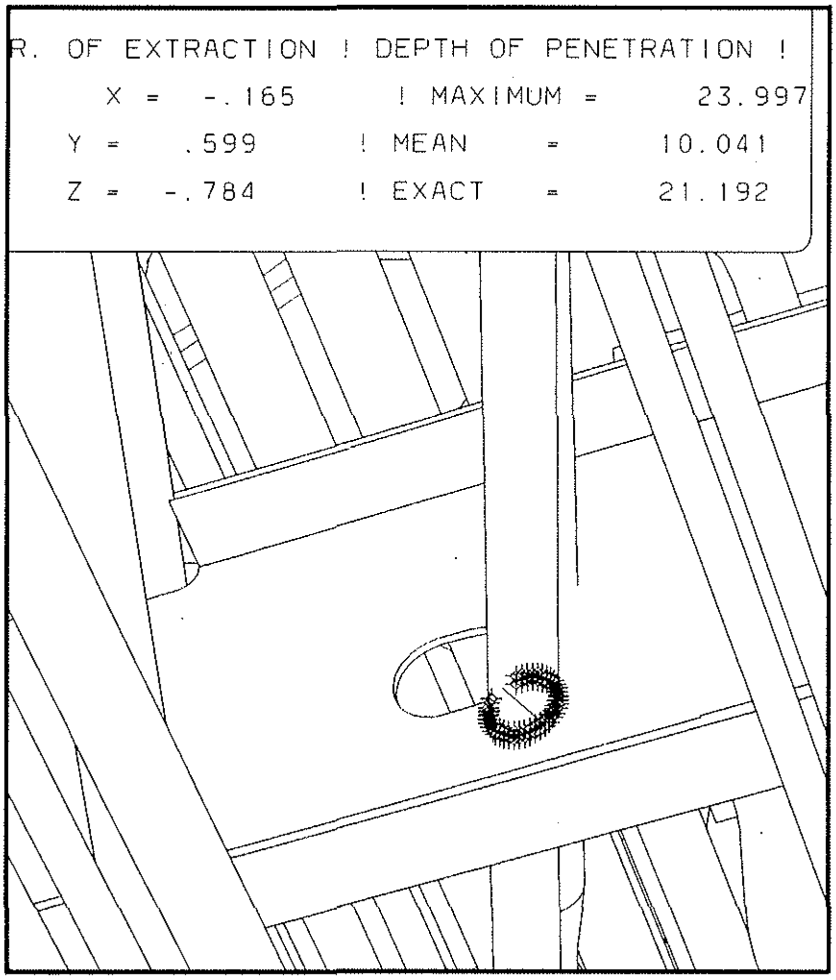
Figure 15: Interference check of Center Fuselage Installation

Figure 15 shows several interferences between structure and subsystems like control system rods and brackets, deicing boxes and electrical harnesses.
All these errors were identified before subsystem release.
After the automatic **CATIA** interference check the results such as type of elements, direction of extraction and depth of penetration are shown in a alphanumeric window.
All of this information helps the designer to relocate their subsystems for a collision free installation.



Interaction between right deicing box and upper deck structure (Longeron APU, Rib APU) with a maximum depth of penetration of 125 mm (Interactions are shown with +)

Figure 16: Detail Figure 15 (Interference between structure and deicing box)



Interaction between Frame 5 and control rods caused to a wrong cut-out.
Maximum depth of penetration 24mm.
(Interactions are shown with +)

Figure 17: Detail Figure 15 (Interference between structure and control rod

5.8. ANTHROPOS

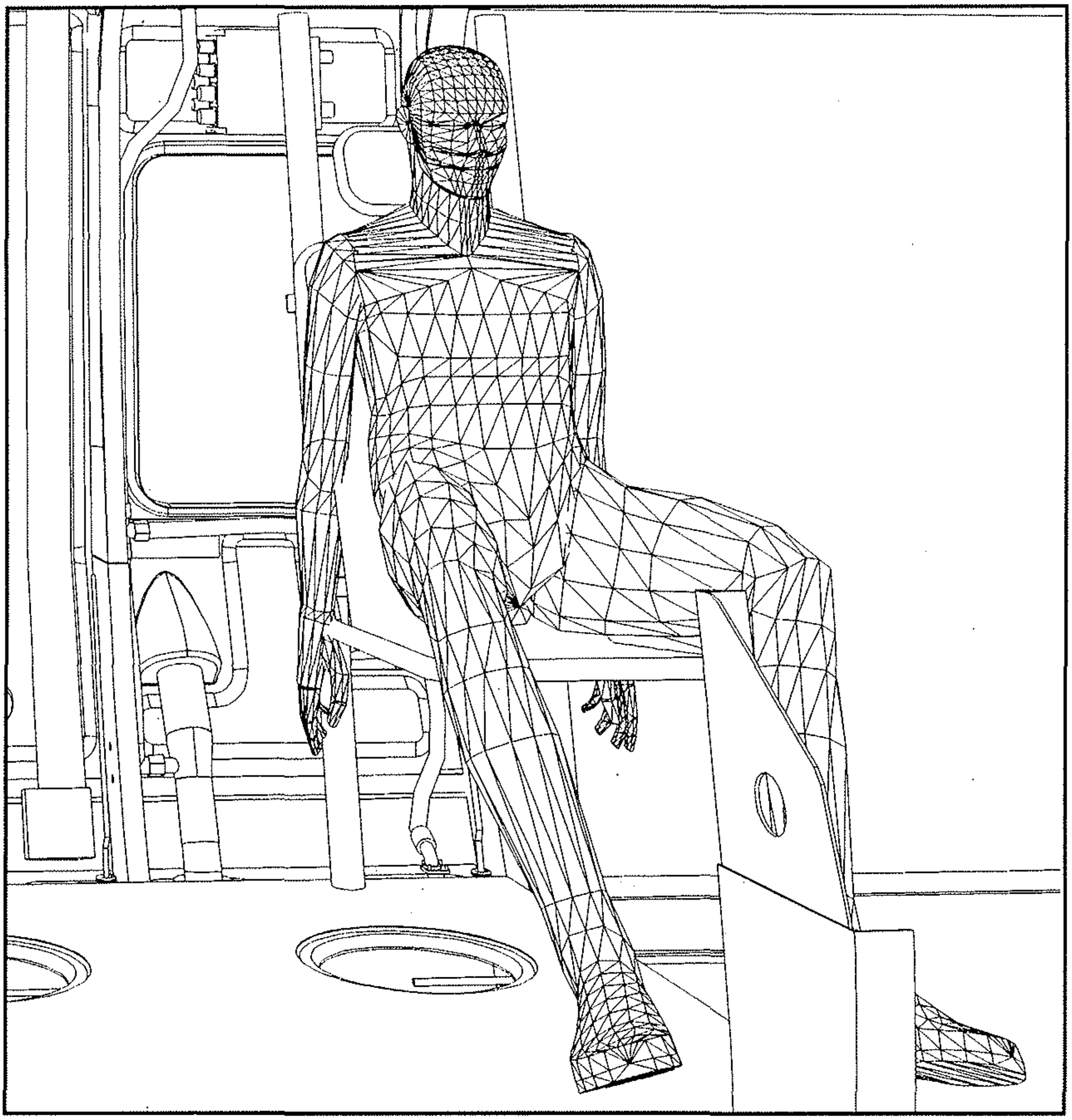


Figure 18: View of ANTHROPOS sitting in a Crew Seat

To accomplish maintainability tasks (e.g. accessibility, replaceability, servicing and ergonomics on a digital mockup a new software package running under **CATIA** called **ANTHROPOS** is used in the **NH90** program. **ANTHROPOS** is an ergonomic software which was developed by IST GmbH
The main characteristic of this tool is a very productive computerized human model. More than 11 million combinations, composed of physique, nations and age,are easy to handle.
A modified version of **ANTHROPOS** will be able to balance *"himself"* by moving his legs and the whole body like a real human being. Additionally, the field of view will be able to be displayed which is very important for accessibility studies related to hidden mountings of integrated equipment.

6. Prospects and Summary

Electronic MockUp's offer the ability to completely integrate all engineering design data into a **3D** digital model for development of system routings, checks for interferences and validating designs prior release.
The **EMU** is applied in the **NH90** program by all four partner companies (*Eurocopter France, Agusta, Fokker and Eurocopter Deutschland)* to achieve an effective cost and time saving development process.

The **EMU** work on the **NH90** program is based on a common methodology, **CATIA** version and supporting **IUA** macros.

As new tools, such as

- newer versions of **CATIA**
- holography of **3D** data
- virtual reality (cyber space)
- material management
- integrated configuration management data

become available, the **NH90** program will benfit, with an increase in effectivity and transparency of the design data

7. Reference

- Electronic Mockup Realisierung und Perspektiver aus Sicht der Vorentwicklung bei der "Deutche Airbus GmbH"
  Deutcher Luft- und Raumfahrt kongreß 1992
  DLRG Jahrestagung 29.09. - 02.10. 1992 in Bremen

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  47th Annual Forom of the American Helicopter Society, Phoenix, Arizona, May 1991

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