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RESUMO - NOTAS / ABSTRACT - NOTES

In the phase I report (INPE-4181-RPE/173) all necessary requirements for the development and construction of a tankage element were described. Considering the present manufacturing capacities in Brazil and available infrastructure in INPE, one has to have a basis for further decisions in the development program, whether it is possible or not to provide a tankage element for the first Brazilian made satellite in the proposed time schedule. This phase II report concerns an approach on the development of the tankage element, including cooperation programs with foreign countries, existing development, and financial requirements.

OBSERVAÇÕES / REMARKS

RESUMO

No relatório da fase I (INPE-4181-RPE/173) todos os requisitos necessários para o desenvolvimento e a construção de um tanque foram descritos. Considerando as atuais capacidades de fabricação brasileiras e a infraestrutura disponível no INPE, é necessária a criação de uma base para decisões futuras no programa de desenvolvimento, se é ou não possível providenciar um tanque para o primeiro satélite brasileiro dentro do cronograma previsto. Este relatório da fase II abrange uma aproximação do desenvolvimento do tanque incluindo programas de cooperação com países estrangeiros, desenvolvimento existente e requisitos financeiros.

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1. INTRODUCTION

In the Phase I report (Feasibility Study of Development and Construction Requirements of a Liquid Propellant Tankage Element) all necessary information for the design, fabrication, test and acceptance of a tankage element had been summarized and a check list on all subjects gave the basis for further project decisions. This Phase II report concerns an approach on a development strategy based on:

- technology transfer proposals;
- available data on the tankage element;
- existing development in INPE;
- necessary know how;
- financial requirements;
- references.

Since the decision for one or another approach depends highly on the institutional, political, and financial situation, the conclusion was made on the experience with the ongoing project philosophy in MECB. It was considered:

- to develop an adequate infrastructure in the country,
- to gather as much as possible know how from a foreign contractor, and
- to be able to provide a space approved tankage element in time,

spending as less money as possible.

This proceeding requires a certain flexibility in the administration in order to sandwich the individual tasks and provide funds in the right moment.

After approval of the described approach on the development of a tankage element, it shall serve as the basis for a detailed planning scheme and a preliminary design study.

2. REFERENCES

Prior to any costly activity, a literature survey was carried out in order to collect information on the state of art of tankage element design. However, extremely new designs are not described anywhere in detail. They are kept secret by the developing companies or governmental institutions.

In Table 1 the references concerning a tankage element available from the library of INPE are summarized. They are grouped into:

- general descriptions;
- materials;
  - * metallic,
  - * elastomers;
- designs;
- calculations;
- test procedures;
- standards and norms.

Furthermore some plain descriptions and pictures from the main space agencies SEP/France, MBB/ERNO/Germany, NASA/USA, and their subcontractors are available.

The literature survey is not concluded, and is continuously updated.

3. AVAILABLE TANKAGE ELEMENT DATA

3.1 - ANSWERS ON THE CHECK LIST

In the Phase I report, one prepared a check list on various items which have to be cleared or give information for the tankage element design. Some of these information are needed in the early state of the development; others may wait until the tankage element is ready for assembly, functional tests or integration.

The check list in Table II was answered consulting the available MECB documentation and using information from the respective responsible persone. Many subjects are scheduled to be treated in late 1987 or even later (MECB A-ETD-0008), though no information is yet available. An answer of absolute "NO" was only given when the subject had not been scheduled in any program task and also the availability in a foreign company would make the development of the tankage element practically impossible, e.g. pressure test bench. This equipment has to be developed and built in parallel to the main development tasks.

3.2 - AVAILABLE DATA

The answers on the check list revealed the following preliminary data:

- propellant: hydrazine;
- propellant load: 20 to 25 litres;
- pressure: 22 to 30 bars;
- blowdown : 4:1;
- shape of tank: sperical;

- management system:diaphragm (bladder);

- lifetime : 2 years.

It could be seen that in the moment only some superficial information is available.

4. FOREIGN CONTRACTORS

4.1 - TECHNOLOGY TRANSFER PROPOSALS

In the year 1986 it was already investigated which foreign companies would be able to furnish a tankage element. At that time one looked especially for a cooperation program on know-how and technology transfer, including the fabrication of a tankage element. Two companies, SEP and MBB/ERNO, finally proposed a cooperation program concerning a complete monopropellant propulsion system (Appendixes A and B). The proposals differ greatly in content and price.

The MBB proposal is restricted to know-how and technology transfer without delivery of any hardware, while the SEP proposal includes the fabrication of one tank in France and assistance in all fabrication steps and test procedures when manufacturing a second tank in Brazil.

The prices are:

MBB/ERNO	DM	500.000	= US$	280.000
SEP	FF	10.000.000	= US$	1.720.000

Both programs need on the Brazilian side the same investment in:

- personnel;
- test equipment;
- instrumentation;
- fabrication facilities.

4.2 - MANUFACTURERS

Besides the cooperation programs, there is the possibility simply to order a complete space accepted tankage element.

There exist various manufacturers, but up to now no one of those had been asked to put forward a proposal. However, through personal contacts it is known that a tank is not available "off the shelf". Delivery time is approximately one year after specification, and the price is in the order of US$ 50.000. The manufacturer allows the control of the fabrication steps and participation in all tests, but gives no information concerning design, construction, fabrication processes and test equipment.

4.3 - COOPERATION WITH RUSSIA OR CHINA

The visits to the space agencies in Russia and China opened the possibilities of exchange of know-how. Since up to now no cooperation program on any matter has been signed, this option may be valuable in the far future.

5. EXISTING DEVELOPMENT IN INPE

Since the implementation of the MECB A-82 program phase (1985), the development of the complete propulsion system was established in the Department of Energy. The tankage element was considered not to have priority, though the work on it was initiated only in February 1987.

Besides this, on more or less own initiative, a group of technicians (Departamento de Recursos Técnicos) dedicated to the development of composite material structures modified an existing wrapping machine and is now able to start with the development of spherical composite material reinforced propellant tanks.

6. NECESSARY KNOW-HOW

The development of the tankage element requires the knowledge in the following areas:

- metallurgy;
- metal processing;
- metal working;
- welding processes;
- composite material processing;
- elastomer material processing;
- gas dynamics;
- hydrodynamics;
- pressure vessel calculation;
- pressure vessel construction;
- stress analysis;
- chemistry of propellants;
- chemistry of surface treatment;
- instrumentation;
- data acquisition;
- testing methods;
- quality control;
- norms.

The knowledge in these areas doesn't need to be accumulated in INPE, if adequate administrative regulations permit to contract services from other companies.

Although this would cut costs and personnel, there is a need of at least:

- two engineers and

- three technicians,

who have to dedicate full time to the project.

7. SOLUTIONS

An approach on the development of the tankage element for the first remote sensing Brazilian satellite has to be seen under the following aspects:

- Time: The tank has to be ready until the beginning of 1990.

- Personnel: The department is short of people and there are no reasons to expect an improvement of the present situation.

- Funds: The budget in the past was always very restricted and one should not expect a sudden change.

- Infrastructure: Especially for the tankage element neither there exists a technical infrastructure (test equipment, instruments), nor any was planned.

- Manufacturers: Although there does exist the industrial capacity to fabricate a tank in Brazil, no exploration of potential suppliers has been possible under the existing budget constraints.

Furthermore, it has to be considered that the development of the tankage element has to follow other rules rather than the development of, for example, electronic hardware or the monopropellant propulsion motor. Right away from the early beginning:

- the proper materials,
- the adequate welding method,
- the right sized shape and
- the right fabrication processes

have to be used.

Otherwise tests on compatibility with the propellant, welding porosity, pressure, and expulsion are not realistic. Also the costs of tools and jigs would be highly increased.

Therefore the development has to be supported immediately with a sufficient large budget in order to be able to construct some full scale tank models and the necessary test equipment.

INPE could opt for several development approaches:

a) try to make all on their own;

b) sign a cooperation with SEP;

c) sign a cooperation with ERNO, Russia or China, and fabricate a tank in Brazil;

d) buy a tank ready.

The solutions a), b) and c) are expensive and would under the above mentioned aspects never lead to a space approved tankage element until 1990. The experience from foreign manufacturers show that even under extremly favorable conditions, the development of a tankage element requires at least two years. This does not include the development and fabrication of absolute necessary test benches and instrumentation, let alone the development of computer programs for pressure vessel calculations and stress analysis.

Even if INPE agrees on the cooperation with SEP this very day, dedicating three engineers exclusively to the project, and provides the necessary test equipment, there is no chance whatsoever to have a tankage element ready in the proposed MECB time schedule.

A realistic approach would be to run the project threefold:

a) Specify a tankage element as soon as possible and order it from a competent foreign supplier at least in early 1988.

b) Apply in 1988 for the cooperation with ERNO or a similar one with China in order to complete the actual know-how.

c) Strengthen the activities in INPE to such a point that the existing know-how together with the international cooperation program allows the setup of the infrastructure for future tankage element fabrication and test in Brazil.

d) Extend with more financial support the composite material reinforced tankage element development in INPE.

This concerted action has the advantage to have a tank ready for the first remote sensing satellite, promote the capabilities of INPE personnel and Brazilian manufacturers for future fabrication and tests, and the whole program is relatively cheap.

8. FINANCIAL REQUIREMENTS

The financial requirements are obviously linked to the approach which is finally agreed on.

The only exactly known numbers are:

SEP contract US$ 1.720.000

ERNO contract US$ 280.000

A complete tank from a foreign supplier may cost:

US$ 50.000

If it is agreed on the described solution, the costs are estimated at:

1987/88	Cooperation ERNO	US$ 280.000
	Tool materials, instruments	US$ 15.000
1988	Test equipment, material research	US$ 70.000
1989	Test equipment, material research	US$ 50.000
	Tank	US$ 50.000
1990	Tools, jigs	US$ 20.000

9. CONCLUSION

Analysing the actual situation of the development of the tankage element, one concludes on an approach which provides a tankage element for the first remote sensing Brazilian satellite, and combines low costs with a maximum of achievable know-how and infrastructure development.

The analysis took in account the today available data on the tankage element, existing development in INPE, personnel and financial requirements, and possible foreign contractors. It is conluded that the first tank has to be bought, while in parallel, through an international cooperation, the existing know-how is completed, and the national infrastructure for future fabrication and test is installed.

Besides this, the internal INPE development activities have to be extended and outfitted with appropriate test equipment.

TABLE 1

LITERATURE SURVEY

GENERAL DESCRIPTION

TITLE	COPY IN DEPT	FRONT PAGE
- A Survey of Current Developments in Surface Tension Devices for Propellant Acquisition.	X	
- Space Shuttle Reaction Control Subsystem Propellant Acquisition Technology.	X	
- Surface Tension Propellant Management System For Aerospace Vehicles.	X	
- Selection of a Surface-Tension Propellant Management System for the Viking 75 orbiter.	X	
- An All Aluminum Propellant Tank	X	
- Liquid Propellants and Combustion	X	
- Analysis and Modeling of Fluid Transfer in Orbit	X	
- Design and Qualification of the Arabsat Propellant Tank	X	
- Design and Qualification of the Eurostar Propellant Tank	X	
- Design and Operational Performance of the Insat-I Propellant Tank.	X	
- Lighter Weight Fiber/Metal Pressure Vessels Using Carbon Overwrap.	X	
- Expendable Resupply Fluid System Design Issues	X	
- Development of a Telecommunication Spacecraft Prop. Tank	X	
- An 18,3 Liter Composite Tank for the German DFS Sat.	X	
- Ring Baffle Pressure Distribution and Slosh Damping in Large Cylindrical Tanks.	X	
- Rotary Balance Data for an F-15 Model	X	
- Gaseous-Helium Requirements for the Discharge of Liquid Hydrogen From a 3,96m Ø Tank	X	
- Head to Base Transfer Function Characteristics of a Cylindrical Tank Partly Filled with Liquid	X	
- Vapor Ingestion in Centraur Liqu. Hydrogen Tank	X	
- Comp. Prog. for Pressurization (Ramp) and Pressurized Expulsion From a Cryogenic Liq. Propellant Tank.	X	

CALCULATION

TITLE	COPY IN DEPT	FRONT PAGE
- Slosh Dynamics in a Toroidal Tank	X	
- Effect of Internal Pressure on Stresses and Strains in Bolted - Flanged Connections	X	
- Zero Gravity Equilibrium Configuration of Liquid Vapor Interface in Toroidal Tanks		X
- Study of Liquid Dynamics in Rocket Propellant Tanks		X
- Study of the Stress Wave Factor Technique for Nondestructive Evaluation of Comp. Materials		X
- Prediction of Propellant Tank Pressurization Requirements by Dimensional Analysis		X
- Balloon Tank Skin Strain Measurements At Liquid Hydrogen Temperature on Centaur Flight Vehicle.		X
- Analytical Treatment of Gas Flows Through Multilayer Insulation		X
- Proposal for Determining the Mass of Liquid Propellant Within a Space Vehicle Propellant Tank Subjected to a Zero Gravity Environment		X
- Effect of Radius on Bulging and Fracture of Through-Cracked Cylindrical Pressure Vessels at Cryogenic Temperature		X
- A Computer Program for the Calculation of Thermal Stratification and Self Pressurization in a Liquid Hydrogen Tank		X
- Program User's Manual for Optimizing the Design of a Liquid or gaseous Propellant Rocket Engine with the Automated Combuster Design Code.		X

DESIGN

TITLE	COPY IN DEPT.	FRONT PAGE
- ALPS General Tank and Cell Assembly	X	
- Ring Damping of Free Surface Oscillations in a Circ. Tank	X	
- Experimental and Studies of Liquid Sloshing at Simulated Low Gravity	X	
- Propellant Slosh Loads	X	
- IAF 82 357 Ensemble Proplusiy de la Plateforme Spot	X	
- Liquid Sloshing in Spherical Tanks	X	
- Dynamic Behavior of Liquid in Moving Container	X	
- Design and Operational Performance of the Insat 1 Propellant Tank Assembly	X	
- Structural Configurations, Analyses, and Materials for Space Vehicles	X	
- Chapter VIII Design of Propellant Tanks	X	
- Contoured Tank Outlets for Draining of cylindrical Tanks in Low-Gravity Environment		X
- Design of Galvanizing Tank	X	

TEST PROCEDURES

TITLE	COPY IN DEPT	FRONT PAGE
- Leak - Before - Burst Criteria Applied to Cryoformed Pressure Tanks	X	
- Shock, Vibration and Associated Environments Part II		X
- Development and Validation of Purged Thermal Protection Sytems For Liquid Hydrogen fuel Tanks of Hypersonic Vehicles		X
- Preliminary Vibration, Acoustic, and Shock Design and Test Criteria for Components on the Light Weight External Tank (LWT) of the Space Shuttle		X
- Test Program to Demonstrate the Stability of Hydrazine in Propellant Tanks		X
- Workbook for Predicting Pressure Wave and Fragment Effects of Exploding Propellant Tanks and Gas Storage Vessels		X
- Vibration, Acoustic, and Shock Design and Test Criteria for Components on the Solid Rocket Boosters (SRB), Light Weight External Tank (LWT), and Space Shuttle Main Engines (SSME).		X

MATERIAL METALLIC

TITLE	COPY IN DEPT	FRONT PAGE
- Equipment and Procedures for Glass-Bead Peening Titanium-Alloy Tanks		X
- Low-Temperature Forming of Beta Titanium Alloys		X
- Elevated Temperature Behavior of Superplastically Formed/Weld-Brazed Titanium Compression Panels Having Advanced Shaped Stiffeners		X
- Nitriding of Titanium and Titanium 8% Aluminium - 1% Molybdenum - 1% Vanadium Alloy with an Ion Beam Source		X
- Fracture Toughness of Wide 2014 - T6 Aluminium Sheet a T - 320^{o}F		X
- Selected Fretting Wear-Resistant Coatings for Titanium - 6% Alu - 4% Vanadium Alloy		X
- Strain - Rate Sensitivity of Three Titanium Alloy Sheet Materials After Prolonged Exposure at 550^{o}K		X
- Texture Strengthening and Fracture Toughness of Titanium Alloy Sheet at Room and Cryogenic Temperatures		X
- Fundamental Mechanisms of Tensile Fracture in Aluminium Sheet Unidirectionally Reinforced with Boron Filament.		X

MATERIAL ELASTOMERS

TITLE	COPY IN DEPT	FRONT PAGE
- Long Time Dynamic Compatibility of Elastomeric Materials With Hydrazine	X	
- Polymers and Their Properties Volume I: Fundamentals of Structure and Mechanics		X
- Mechanical Design Handbook for Elastomers		X
- Fibres, Films, Plastics and Rubbers		X
- Design Engineering Series Rubbers		X
- ASRDI Oxygen Technol, Survey Chapter 9:Rubber Seal	X	

STANDARDS NORMS

TITLE	COPY IN DEPT	FRONT PAGE
- Chapa de Alumínio e de Ligas de Alumínio	X	
- Alumínio e Suas Ligas	X	
- Alumínio e Suas Ligas-Têmperas	X	
- Chapas de Alumínio e Suas Ligas-Tolerâncias Dimensionais.	X	
- Alumínio e Ligas de Alumñio-Terminologia	X	
- Alumínio e Suas Ligas-Propriedades Mecânicas de Produtos Extrudados - Especificação	X	
- Standard Practice for Preparation of Titanium and Titanium Alloys for Electroplating	X	
- Descalling and Cleaning Titanium and Titanium Alloy Surfaces	X	
- Preparation, Standardization, and Storage of Standard Solutions for Chemical Analysis	X	

TABLE 2

TANKAGE ELEMENT DESIGN

Check list on the feasibility	Data, Equipment, Infrastructure, available			If yes where			If later where				Necessary for
Subject	yes	no	later	INPE	BRASIL	OTHER	when	INPE	BRASIL	OTHER	
Mission Criteria											Propellant budget
Duration	X										
Task	X										
Maneuvers in orbit			X				1987	X			
Safe hold			X				1987	X			
Orbit keeping			X				1987	X			
Propulsion System Requirements											Design, Materials, Size, Shape, Structure
Propellant	X			X							
Oxidizer		none									
Pressure	X										
Flight loads (accelerations x,y,z)			X				1987	X			
Propellant load			X				1987	X			
Blow down ratio	X			X							
Flow rates			X				1987	X			
Ground Handling and preflight conditions											Design, Support, Piping, Fuel management, Structure
Transportation mode			X				1990	X			
Accelerations x,y,z			X				1990	X			
Shocks			X				1990	X			
Vibrations			X				1990	X			
Acoustic			X				1990	X			
Storage temperature			X				1990	X			
Storage duration			X				1990	X			

Check list on the feasibility	Data, Infrastructure Equipment available			If yes where			If later where				Necessary for
Subject	yes	no	later	INPE	BRASIL	OTHER	when	INPE	BRASIL	OTHER	
Launch vehicle environment											Design,
Storage temp.			X				1988		X		Support,
Operating temp.											Piping,
Vibration x,y,z											Fuel - management,
Acceleration x,y,z											Structure
Acoustic											
Kick out shock											
Injection error											
Space vehicle Definition											Design,
Available space			X				1987	X			Piping,
Packing			X					X			Type,
Support			X					X			Overall
Fill port location			X					X			Calculation, Structure
Drain port location			X					X			
Pressure port location			X					X			
Line to thruster (s)			X					X			
Inspection holes			X					X			
Integration			X					X			
Center of gravity			X					X			
Operating temperature			X					X			
Orbit control Attitude control			X					X			
Instrumentation *pressure *temperature			X					X			

Check list on the feasibility	Data, Infrastructure, Equipment available			If yes where			If later where				Necessary for
Subject	yes	no	later	INPE	BRASIL	OTHER	when	INPE	BRASIL	OTHER	
Infrastructure											Management
Administration System											Contracts
											Calculations
Program management			X				1987	X			Operation of test equipment
Funds			X				1987	X			Fabrication
Quality control			X				1988	X	X		Inspection
Personnel			X				1987	X			
Laboratory for Inspection											Material
											analyses
Chemical			X				1988	X			Material properties
Mechanical			X				1988	X			Dimensions, Tolerances
Metrological			X				1988	X			
Laboratory for tests											Compatability of materials
Chemical Solutions			X				1988	X			with propellant
Ultrasonic bath			X				1988	X			
Mechanical Equipment			X				1988	X			
Helium leak detector			X				1988	X			Leakage
Hydrazine detector			X				1988	X			
Tensile test machine			X				1988		X		Stresses
Tensile fatigue test machine			X				1988		X		Fatigue
X-ray machine			X				1987		X		Welding
UV - penetrant machine			X				1987		X		Welding

Check list on the feasibility	Data, Infrastructure, Equipment available			If yes where			If later where				Necessary for
Subject	yes	no	later	INPE	BRASIL	OTHER	when	INPE	BRASIL	OTHER	
Vibration table with dedicated computer and analysis-software			X				1988	X			Vibration test
Test bench to fill and measure expulsion		X									Expulsion Efficiency Fill drain Procedure
Test bench to pressurize tank up to burst pressure		X									Pressure test Pressure cycling test
Acceleration test bench with dedicated computer		X									Acceleration test
Drop tower with dedicated photographic equipment and computer system		X									Slosh test
Laboratory for assembly clean room			X				1988	X			Assembly
Cleaning equipment with particle size measuring instruments		X									Cleanliness
Tools Jigs Measurement-Equipment		X									Assembly

Check list on the feasibility	Data, Infrastructure, Equipment available			If yes where			If later where				Necessary for
Subject	yes	no	later	INPE	BRASIL	OTHER	when	INPE	BRASIL	OTHER	
Laboratory for Integration											Integration
Clean room			X				1989	X			
Jigs			X					X			
Mock-up			X					X			
Mechanical Shops											Fabrication and assembly
Molding facilities	X				X						
Furnaces	X				X						
Power press	X				X						
High precision lathe with copying equip. or NC	X				X						
TIG-welding machine	X				X						
Electro beam welding machine	X				X						
Composite Material	X			X							Fabrication
Processing Machines											
Wrapping machine	X			X							

APPENDIX A

PROPOSTA DE COOPERAÇÃO TÉCNICA

MBB ERNO

Raumfahrt

ERNO
Raumfahrttechnik
GmbH

Instituto De Pesquisas Espaciais
Attn.: Dr. Joao Andrade de Carvalho jr.
Caixa Postal 01
12630 Cachoeira Paulista
S. Paulo
B R A Z I L

RB526/HSaz 4335 04.07.86

ERNO Proposal No. 860 2ZE1 703

Subject: Proposals for Technology Transfer

Ref.: Your visit on 03.06.86

Dear Mr. Carvalho,

Thank you for giving us the opportunity to quote for the transfer of technology as requested by you during your visit at our facilities on 3rd June, 1986.

We have split the overall hydrazine technology transfer into three programs, dealing with:

program 1: Handling, Safety and Analysis Methods of Hydrazine

program 2: Design of a 4.0 N Hydrazine Thruster and Flow Control Valve

program 3: Design of a Hydrazine Diaphragm Propellant Tank.

The three programs above have been described in detail. However, we are sure that, after having studied them, a variety of questions will still have to be answered. Thus the prices calculated for the three programs will have to be discussed as well, as for program 2 e.g. variations or additions have been defined and quoted as well.

Furthermore, the contract conditions have to be negotiated - among others:

- the use of the transferred technology

  a) for use on MECB
  b) for use on national brazilian satellites
  c) for other programs

Dr. Joao Andrade de Carvalho jr.	MBB	ERNO
vom 04.07.86		
Blatt -2-		

° the additional support requested

a) in Germany at MBB/ERNO
b) in Brazil (INPE)

° the licence agreement.

As all these items have to be discussed in detail, the prices given below are open to discussion as well and are for information only.

The prices for the above programs are (at 1986 economic conditions):

program 1:		DM 250.000
program 2:	step 1	DM 750.000
	step 2	DM 1.250.000
	structural/thermal analysis	DM 100.000
program 3:		DM 500.000

We hope that the programs which have been defined fulfill your requirements and invite you to discuss their contents, sequence and the methods described with us.

Due to holiday period you may contact Mr. J. Gülpen, phone 421-5394246, as of 24.07.86 or Mr. H.D. Schmitz, phone 421-5394335, as of 04.08.86.

Yours sincerely,

ERNO Raumfahrttechnik GmbH

i.V. Ludwig ppa. Schwarze

MBB ERNO

TECHNOLOGY TRANSFER

Program 3 Design of a Hydrazine Diaphragm Propellant Tank

a) Subject of Technology Transfer

The diaphragm propellant tank consists of the

- tank shell and the
- rubber diaphragm.

MBB/ERNO - though being a supplier of propellant tanks, above all of surface tension tanks - has not yet qualified and flow diaphragm tanks built to its own design. However, we do have a diaphragm tank design which has been achieved in a special research and development program. This design will be subject of this proposed technology transfer program.

The diaphragm material being compatible with hydrazine has been developed by a German company. MBB/ERNO cannot transfer any know how on this material as it is not our property. We have received ready molded diaphragms according to mutually agreed design drawings and are sure that the same would apply to INPE-designed diaphragms.

The contents of the propellant tank program would thus be as follows:

1. General Design Requirements

1.1 Material Selection
1.2 Functional Requirements
1.3 Environmental Requirements
1.4 Interfaces

MBB ERNO

2. Applicable Software

2.1 MIL-Specifications
2.2 ESA-Specifications
2.3 Standards, Handbooks, etc.
2.4 Test Procedures
2.5 Drawings
2.6 Manufacturing Procedures

3. Propellant Tank Design

3.1 Structural Design
3.1.1 Stress Analysis
3.1.2 Fracture Mechanics Analysis
3.2 Mounting Provisions
3.3 Diaphragm Design
3.4 Manufacturing Considerations

b) Methods of Technology Transfer

Baseline for the technology transfer is the tank design and the diaphragm know-how derived from different MBB/ERNO research and development programs. Furthermore, the structural analysis techniques resulting from the surface tension tank programs will be considered as well.

After the analysis of available

- Component Specifications
- Acceptance and Qualification Test Procedures and
- Drawings

the technology transfer will be practically performed by

MBB ERNO

a) defining the steps to be performed to establish a tank design

b) performing a preliminary design drawing incorporation the main design features (assembly engineering drawings)

c) performing a stress analysis and a fracture analysis

d) incorporating the analysis results into the final design drawing (assembly engineering drawings)

e) preparation of a diaphragm design drawing

f) discussion of the manufacturing principles, processes and methods

g) establishing acceptance and qualification test programs.

The above design activities will lead to assembly drawings, which should be used to establish a complete manufacturing drawing set (which is not part of this proposal). Not actually included in this program is also the establishment of drawings of the manufacturing tooling. This item will be discussed and a list of the required tooling as far as required from the MBB point of view established.

A discussion of the diaphragm design with the diaphragm manufacturer should be performed in order to clarify the different aspects of

° design and manufacturing
° interfaces and tolerances
° conditions for supply to Brazil.

MBB ERNO

Furthermore, it is recommended that the trainee prepares - if reasonable - a day-by-day report in English on the activities performed and the experience gained during the training program. This report can then be checked by the MBB/ERNO personnel and discussed with the trainee to verify and prove that everything has been understood and can be reproduced on the basis of this report in Brazil.

c) Assumed Capabilities of the Trainee

The trainee should be an educated structural/mechanical engineer with capabilities in

° structural design
° structural and fracture mechanics analyses
° manufacturing aspects (including welding and NOI)

and should be able to read, speak and write in English fluently. A maximum of two engineers should follow the technology transfer program.

d) Assumed Duration

Before starting the technology program a preparation phase at MBB/ERNO is requested of about 3 months to set up the documentation required.

The technology transfer program itself will have a duration of 5 months at MBB/ERNO Bremen and at Ottobrunn for short visits and one or two visits at the diaphragm supplier.

APPENDIX B

PROPOSTA DE COOPERAÇÃO TÉCNICA

WP 100	TANK PMD / DINTEC	DiA	PMD
	Price for activity 110	2 200 000	3 400 000 FF
	Price for transfer of technology	1 300 000	3 000 000 FF
	TOTAL PRICE FOR WP 110	3.500.000	6 400 000 FF
WP 200	TANK SHELL		
	Price for activity 210		2 500 000 FF
	Price for transfer of technology	same	1 000 000 FF
	TOTAL PRICE FOR WP 210		3 500 000 FF
WP 300	TANK ASSEMBLY		
	Price for activity 310		2 500 000 FF
	Price for transfer of technology	same	500 000 FF
	TOTAL PRICE FOR WP 310		3 000 000 FF
	Tanks Total	10.000.000	12.900.000 FF
WP 400	VALVE		
	Price for activity 410		1 500 000 FF
	Price for transfer of technology		1 000 000 FF
	TOTAL PRICE FOR WP 410		2 500 000 FF

6 000 000 | ACT 100 + 300

3 500 000
3 500 000
3 000 000
10 000 000 | 9 000 000 for three activities

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REV.

WORK PACKAGE DESCRIPTION

[illegible] INPE - SEP COOPERATION	W.P. REF.: 111
[illegible]	SHEET 1 OF 1

. TAN P.M.D.

. ACTIVITIES AT SEP

. MANAGEMENT AND TECHNICAL SUPPORT

- Coordination of activities
- Product assurance plan and follow-up
- technical support to INPE Employees during activities in design, manufacturing, inspection, testing.
- Present, comment, explain the design and development of the item in particular with regard to technological choices background.

WORK PACKAGE DESCRIPTION

INPE - SEP COOPERATION

W.P. REF.: 112

SHEET 1 OF 1

. TANK P.M.D.
. ACTIVITIES AT SEP
. STUDIES AND DESIGN DOCUMENTATION

1. [illegible]:

- Produce procurement specification
- Produce design and development plan
- Perform studies of propellant configuration inside the P.M.D.
- Perform sizing calculations and stress analysis

- Produce the material list
- Produce design documentation :
  - . manufacturing drawings set
  - . design specifications
  - . materials and parts procurement specifications
- Design review

WORK PACKAGE DESCRIPTION

PROJECT	INPE - SEP COOPERATION	W.P. REF.: 113
W.P. TITLE	. TANK P.M.D. . ACTIVITIES AT SEP . MANUFACTURE / TEST . TOOLINGS AND DOCUMENTATION	SHEET 1 OF 1

TASKS INCLUDED:

- Produce/update manufacturing and inspection flow-chart
- Produce/update manufacturing procedures
- Produce/update manufacturing processes
- Produce/update process list
- Design/manufacture/update manufacturing toolings
- Produce/update inspection procedures
- Design/manufacture/update inspection toolings
- Produce qualification and acceptance test plans
- Produce/update qualification and acceptance test procedures
- Design/manufacture testing toolings
- Prepare test facilities
- Review of the above documentation

WORK PACKAGE DESCRIPTION

P[illegible] INPE - SEP COOPERATION	W.P. REF.: 114
W[illegible]	SHEET 1 O

. TANK P.M.D.
. ACTIVITIES AT SEP
. MANUFACTURING AND TESTING

W[illegible]:

- Procure materials and parts
- Manufacture/inspect one model of : PMD
- Test the PMD
- Produce the test report
- Test review

WORK PACKAGE DESCRIPTION

P...	INPE - SEP COOPERATION	W.P. REF.: 121
W...		SHEET 1 OF 1

. TANK P.M.D.
. ACTIVITIES IN BRAZIL

. CAPABILITIES SURVEY

T... DESCRIPTION:

- Visit of relevant Brazilian Industry in order to survey necessary facilities for tank manufacturing and testing (machining, welding, inspection, environment test facilities).

- Produce a survey report.

WORK PACKAGE DESCRIPTION

PROJECT : INPE - SEP COOPERATION	W.P. REF.: 122
W.P. TITLE :	SHEET 1 OF 1
. TANK P.M.D.	
. ACTIVITIES IN BRAZIL	
. FACILITIES SETTING UP ASSISTANCE	

TASKS INCLUDED:

- Assistance for producing procurement specifications of new means to be implemented.

- Assistance for setting-up the new facilities

WORK PACKAGE DESCRIPTION

PROJECT: INPE - SEP COOPERATION	W.P. REF.: 123
W.P. TITLE . TANK P.M.D. . ACTIVITIES IN BRAZIL . MANUFACTURING AND TESTING ASSISTANCE	SHEET 1 OF 1

TASKS INCLUDED:

- Assistance for manufacturing, inspection and testing of one model of PMD

- Test review assistance.

WORK PACKAGE DESCRIPTION

P... INPE - SEP COOPERATION	W.P. REF.: 21
W.P	SHEET 1 (1
. TASK SHEET . . ACTIVITIES AT SEP . . MANAGEMENT AND TECHNICAL SUPPORT	

TASK DESCRIPTION:

- Coordination of activities
- Product assurance plan and follow up

- Technical support to INPE Employees during component activities in France in design, manufacturing, inspection, testing.

- Present, comment, explain the design and development of the item in particular with regard to technological choices background.

WORK PACKAGE DESCRIPTION

PROJECT INPE - SEP COOPERATION	W.P. REF.: 212
W.P. TITLE . TANK SHELL . ACTIVITIES AT SEP . STUDIES AND DESIGN DOCUMENTATION	SHEET 1 OF 1

TASKS INCLUDED:

- Produce procurement specification
- Produce design and development plan
- Perform sizing calculations and stress analysis
- Produce the material list
- Produce design documentation :
  - . manufacturing drawings set
  - . design specifications
  - . materials and parts procurement specifications
- Design review

WORK PACKAGE DESCRIPTION

PROJECT: INPE - SEP COOPERATION	W.P. REF.: 213
W.P. TITLE: . TANK SHELL . ACTIVITIES AT SEP . MANUFACTURE / TEST TOOLINGS AND DOCUMENTATION	SHEET 1 OF 1

TASKS INCLUDED:

- Produce/update manufacturing and inspection flow-chart
- Produce/update manufacturing procedures
- Produce/update manufacturing processes
- Produce/update process list
- Design/manufacture/update manufacturing toolings
- Produce/update inspection procedures
- Design/manufacture/update inspection toolings
- Produce qualification and acceptance test plans
- Produce/update qualification and acceptance test procedures
- Design/manufacture testing toolings
- Prepare test facilities
- Review of the above documentation

WORK PACKAGE DESCRIPTION

PROJECT	INPE - SEP COOPERATION	W.P. REF.: 214
W.P. TITLE	. TANK SHELL . ACTIVITIES AT SEP . MANUFACTURING AND TESTING	SHEET 1 OF 1

TASKS INCLUDED:

- Procedure materials, forgings and parts
- Manufacture/inspect one model of shell
- Produce the test report
- Test review

TASK EXCLUDED

Final welding of the shell (in order to be able to incorporate the PMD).

WORK PACKAGE DESCRIPTION

PROJECT	INPE - SEP COOPERATION	W.P. REF.: 221
W.P. TITLE	. TANK SHELL . ACTIVITIES IN BRAZIL . CAPABILITIES SURVEY	SHEET 1 OF 1

TASKS INCLUDED:

- Visit of relevant Brazilian Industry in order to survey necessary facilities for tank manufacturing and testing (machining, welding, inspection, environment test facilities, leakage measurement ...).

- Produce a survey report.

WORK PACKAGE DESCRIPTION

PROJECT INPE - SEP COOPERATION	W.P. REF.: 222
W.P. TITLE TANK SHELL . ACTIVITIES IN BRAZIL . FACILITIES SETTING-UP ASSISTANCE	SHEET 1 OF 1

TASKS INCLUDED:

- Assistance for producing procurement specifications of new means to be implemented.

- Assistance for setting-up the new facilities.

WORK PACKAGE DESCRIPTION

PROJECT: INPE – SEP COOPERATION	W.P. REF.: 223
W.P. TITLE: . TANK SHELL . ACTIVITIES IN BRAZIL . MANUFACTURING AND TESTING ASSISTANCE	SHEET 1 OF 1

TASKS INCLUDED:

- Assistance for manufacturing, inspection and testing of one model of shell.

- Test review assistance.

WORK PACKAGE DESCRIPTION

PROJECT INPE - SEP COOPERATION	W.P. REF.: 311
W.P. TITLE . TANK (SHELL + PMD) . ACTIVITIES AT SEP . MANAGEMENT AND TECHNICAL SUPPORT	SHEET 1 OF 1

TASKS INCLUDED:

- Coordination of activities
- Product assurance plan and follow-up
- Technical support t INPE Employees during component activities in FRANCE in design, manufacturing, inspection, testing.
- Present, comment, explain the design and development of the item in particular with regard to technological choices background.

WORK PACKAGE DESCRIPTION

P... INTAS - SEP COOPERATION	W.P. REF.: 312
V: . TA... (SHELL + PMD) . ACTIVITIES AT SEP . STUDIES AND DESIGN DOCUMENTATION	SHEET 1 O. 1

TA... [illegible]:

- Produce procurement specification
- Produce design and development plan
- Perform studies of propellant configuration
- Perform sizing calculations and stress analysis

- Produce the material list
- Produce design documentation :
  - . manufacturing drawings set
  - . design specifications
  - . materials and parts procurement specifications
- Design review

WORK PACKAGE DESCRIPTION

PROJECT	INPE - SEP COOPERATION	W.P. REF.: 313
W.P. TITLE	. TANK (SHELL + PMD) . ACTIVITIES AT SEP . MANUFACTURE / TEST TOOLINGS AND DOCUMENTATION	SHEET 1 OF 1

TASKS INCLUDED:

- Produce/update manufacturing and inspection flow-chart
- Produce/update manufacturing procedures
- Produce/update manufacturing processes
- Produce/update process list
- Design/manufacture/update manufacturing toolings
- Produce/update inspection procedures
- Design/manufacture/update inspection toolings
- Produce qualification and acceptance test plans
- Produce/update qualification and acceptance test procedures
- Design/manufacture testing toolings
- Prepare test facilities
- Review of the above documentation

WORK PACKAGE DESCRIPTION

PROJECT	INPE - SEP COOPERATION	W.P. REF.: 314
W.P. TITLE	. TANK (SHELL + PMD) . ACTIVITIES AT SEP .. MANUFACTURING AND TESTING	SHEET 1 OF 1

TASKS INCLUDED:

- Tank final assembly
- Test the tank
- Produce the test report
- test review

TASKS EXCLUDED :

- Manufacture of SHELL
- Manufacture of PMD

WORK PACKAGE DESCRIPTION

PROJECT INPE - SEP COOPERATION	W.P. REF.: 321
W.P. TITLE . TANK (SHELL + PMD) . ACTIVITIES IN BRAZIL . CAPABILITIES SURVEY	SHEET 1 OF 1

TASKS INCLUDED:

- Visit of relevant Brazilian Industry in order to survey necessary facilities for tank manufacturing and testing (machining, welding, inpection, environment test facilities, leakage measurement ...).

- Produce a survey report

WORK PACKAGE DESCRIPTION

P.[illegible] INPE - SEP COOPERATION	W.P. REF.: 322
W.P. TI[illegible] . TANK (SHELL + PMD) . ACTIVITIES IN BRAZIL . FACILITIES SETTING-UP ASSISTANCE	SHEET 1 O[illegible] 1

TASK [illegible]DED:

- Assistance for producing procurement specifications of new means to be implemented.

- Assistance for setting-up the new facilities.

WORK PACKAGE DESCRIPTION

PROJECT: INPE - SEP COOPERATION	W.P. REF.: 323
W.P. TITLE: . TANK (SHELL + PMD) . ACTIVITIES IN BRAZIL . MANUFACTURING AND TESTING ASSISTANCE	SHEET 1 OF 1

TASKS INCLUDED:

- Assistance for manufacturing, inspection and testing of one model of tank.

- Test review assistance.

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INSTITUTO DE PESQUISAS ESPACIAIS

PROPOSTA PARA PUBLICAÇÃO

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AUTORIA: Jorgdieter Anhalt

PROJETO/PROGRAMA: MECB

DIVISÃO: -

DEPARTAMENTO: DCP

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