CP-602

THOMSON-CSF EXPERIENCE IN AIRBORNE SYSTEM INTEGRATION

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Foreword

The strategic management of the cost issue is of major importance for any company ; basically, the question is to combine the customers' satisfaction and the company's profitability. The customers' satisfaction is met with agreeable and affordable levels of price and performance of the products and systems they buy. The company's profitablility is needed to meet the basic rules of capital and strategic investment.

In our so called "high tech" companies we have also to take account of the huge level of R and D required to run our projects and programs. More and more, this R and D is partially, if not totally, self -funded by the company itself.

Furthermore, cost management must enable us to get the resources which are needed to be in the position to study, then develop and produce the future systems which will be in the Forces, our customers.

Many answers can be given to this difficult question of cost management.

After having introduced my company, THOMSON-CSF/Radars et Contremesures (RCM), and our main airborne systems, I will address our global methodology dedicated to these systems' studies and developments. This methodology, without any doubt, is the fundamental core of our know-how, not only relying on more or less heavy and sophisticated tools, but also and above all fed by the unique skill of our staff, for decades.

Presentation of charts 1 to 6 (RCM and its products and systems overview)

1. INTRODUCTION (CHART 7)

The ultimate aim of any project or program is to respond to a customer requirement. No company can hope to develop—or even survive—unless its customers are satisfied and unless the work for which it is responsible has been carried out in line with forecasts, particularly cost forecasts.

These basic truths are applicable to all types of products and systems, however complex.

- To satisfy a customer, the customer's requirement must first be understood.
- Then there is a need to agree with the customer on the best way of satisfying this requirement with the budget available.
- Finally, the customer must be shown that the requirement has been met, logistic support must be provided as agreed, and subsequent system developments must be proposed if and when the operational context changes.
- In the view of the operation being profitable for the company, there is a need to monitor each step in the program, control the risks involved, and take corrective action as soon as variances or overruns are detected.

There is now a generally accepted working methodology .This presentation does not go into detail about the methodology itself, but uses the basic schema (chart 8) to structure a description of the tools used at successive stages of an onboard systems program.

Paper presented at the AGARD FVP Symposium on "Strategic Management of the Cost Problem of Future Weapon Systems", held in Drammen, Norway, 22-25 September, 1997, and published in CP-602.

- Understanding the customer's requirement (chart 9). Technico-operational simulations, usually man-in-the-loop simulations in real time, are used at this stage. The main example is the METRO simulator.

- Designing systems, developing specifications for the different components (chart 10) and setting operational limitations. Modeling tools are used to model individual items of requirement as well as interactions and possible interference between these items of equipment. The main example used is the SARGASSES simulator.

- Proving that behaviour and performance levels observed experimentally are the same as were predicted and modeled (chart 11).

This needs to be done as early as possible and as soon as the actual components or items of equipment are available. The main example used is Le Mengam test base.

- Showing the customer that the system that will be delivered is really what had been agreed to and satisfies the requirement that had been expressed (chart 12). The main example used is the Thomson-CSF test facility at Brétigny.

All the major companies working in this field use tools of this kind. The capabilities of each tool and the level of coherence between them largely depends on how much has been invested to develop them.

There is such a variety of problems that need to be solved in onboard systems—and the systems themselves are becoming more complex and budgets are getting tighter— that no single electronics company or aircraft manufacturer can hope to maintain all the skills needed all the time. Cooperation is of critical importance.

For onboard systems, there is a clear need for cooperation between aircraft manufacturers and suppliers of electronic systems. Cooperation is also vital between industries and government bodies in the same country or in the other countries taking part in joint programs. Everybody will benefit from effective partnership or closer international cooperation.

2. UNDERSTANDING THE REQUIREMENT (CHART 13)

Understanding the requirement is the most vital link in the system design-production-integration process.

All programs are affected by today's budget restrictions. Right at the beginning of each program, and, regrettably, also while the program is being conducted, successive trade-offs must be made between the operational requirement as expressed, the technical performance needed to meet that requirement, and cost.

These trade-offs are basically achieved on a consensual basis by operational staff or end users, the government bodies in charge of the program, and contractors. It is therefore a question of teamwork. Everybody has to understand the other team members' points of view, and the contractors in particular have to propose price-performance trade-offs that are acceptable to their partners.

Knowing what each solution would cost—which can be difficult in an area that is changing so fast—is clearly crucial to this process of optimization.

This is, and will continue to be, the contractor's basic job. Contractors that want to stay in the running will have to get better at assessing the exact cost of the different solutions.

Knowing how the technical requirement that generates this cost will affect operational performance—which is what end users need to know—is a rarer skill. This is one of the distinctive competencies of the systems supplier.

In many fields, including onboard systems, numerical simulation has become indispensable.

The example given on the chart (chart 14) and shown later in the movie involves real-time man-in-the-loop simulation of air-to-ground functions from combat aircraft or helicopters.

Distributed Interactive Simulation (DIS) standards are used to achieve interoperability between various computing devices installed in different locations, with a view to simulating :

- the environment and its visual representation,
- the aerodynamic behaviour of the platform,
- various air defence systems,
- various self-protection systems,
- various air-to-ground weapons.

The aim of simulation in this case is to assess the probability of destroying a target protected by air defence systems, and to assess the survivability of the aircraft in various self-protection configurations (warning detection, jamming, deception).

The METRO simulator has a lot in common with a pilot training simulator, and was jointly developed by the Thomson-CSF units in charge of training simulators (TT&S), air defence systems (Airsys) and onboard systems (RCM). It is a good illustration of the benefits of using standards and standardised procedures. With this approach, different players in a system can set up a real-time computer model, or a hybrid model incorporating items of real equipment—without all needing to be in the same physical location, and without having to exchange detailed models of the equipment or subsystems for which they are responsible.

This type of tool is already sufficiently mature to gauge how sensitive a given aspect of operational performance is to different technical parameters when the simulation is controlled in real time. Using these tools is an ideal way of achieving the dialogue and mutual understanding needed to define complex systems.

But the complex-system integrator's job does not end here. Once the requirements have been understood, it must be established that the concepts selected are feasible in practice, operational limitations must be stated, risks must be qualified and needs expression and feasibility must be fed into the loop—sometimes with several successive iterations—before a mutual agreement can be reached and the contractor can make a formal commitment to the customer.

The next part of the presentation deals briefly with this second category of tasks, which are generally conducted by industries and often on a

3. RISK ASSESSMENT (CHART 15)

Customer satisfaction depends above all on how well we have understood that customer's requirements. Similarly, the industrial success of a program (in terms of the level of satisfaction of the company's financial director) will depend on how well we have assessed the risks involved and applied the right procedures to reduce those risks to acceptance levels when we made the commitment to the customer.

Here again, usually still at the stage when neither the platform nor the equipment making up the system actually exist, numerical simulation is an essential tool, provided it is used by experienced teams—i.e., teams that have already compared simulations and measurements and that have not lost touch with the practical sense of the engineer.

Major areas of risk for aeronautical systems include :

- Resistance to vibration and impact (deck landings, extreme climates, depressurisation, etc.) (Chart 16)

  The real difficulty is to determine the conditions that will be encountered in real life, as compliance with standards is no longer a sufficient argument in itself and rarely leads to cost optimization.

  In this case, the best chances of success lie in a high-quality relationship between the aircraft manufacturer, who knows the platform better than anybody else, and the equipment supplier who knows the equipment. When aircraft manufacturers and equipment suppliers have gained their experience by working together, this relationship can be of very high quality, and this is an argument in favour of strong partnerships in this area.

- Electromagnetic compatibility is a growing risk, not only because the signals transmitted cover a broader spectrum and threshold voltages on logical gates are lower, but also because modern aircraft are equipped with large numbers of powerful transmitters and highly sensitive receivers.

- Assessment of flows of numerical data, computing times or transmission times are also areas of risk. The chart 17 shows the growing part of electronics since decades, and the induced growing complexity in the airborne systems.

  Assessment of the effects of nearby structures on antenna radiation patterns
  This is often of crucial importance and can lead to a long iterative process with the aircraft manufacturer and the customer.

  Today, a sophisticated electronic warfare system such as the ICMS for the Mirage 2000-5 (Chart 18) can have up to 25 antennas, all additional to the many antennas or aerodynamic sensors that equip the basic airframe. Each antenna in the electronic warfare system must be located in the best possible place on the aircraft, taking into account the pods, weapons or different antennas carried by the aircraft.

  This is a very important problem that requires a very high skill. The objective is to find compromise solutions, and at the very least to identify system limitations and make sure the customer is aware of those limitations.

  This was Thomson-CSF's objective when it developed SARGASSES (chart 19).

  A few comments should be made here about using SARGASSES :

- Results are best when the aircraft can be described in precise detail. Here again, a good relationship between the aircraft manufacturer and the electronic system supplier is extremely important, as only the aircraft manufacturer has the exact computer description of the aircraft.

- SARGASSES can also be used to calculate the radar cross-section of all types of objects. Results are remarkably good.

4. VALIDATION OF TECHNICAL PERFORMANCE (CHART 20)

Using the examples taken to illustrate the major areas of risk, we will now describe the equipment used to check that predicted performance levels are really achieved, to make sure that the risks have been overcome, and to convince the customer that this is the case.

- Mechanical and thermal resistance : conventional equipment such as vibration generators, thermal chambers and depressurisation chambers are used here.

  The modeling is of excellent quality. Referring to vibration on an equipment cabinet, calculated and measured resonance frequencies are only a few thousandths apart.

- Electromagnetic compatibility : individual items of equipment, cabling and, whenever possible, whole systems, need to be tested to avoid costly electromagnetic compatibility problems when they are integrated on board the aircraft.

- To control flows of numerical data and more generally to monitor system operation on the ground, specific system assembly or integration test benches need to be developed.

  The chart (Chart 21) shows the assembly bench for the ICMS integrated countermeasures suite.

  The equipment is interconnected, and each item of equipment can be replaced by a behavioural simulator. We feed the system either with data flows generated by initial modeling sequences, or by using hybrid simulators that generate microwave representations of the operational scenarios that were agreed upon with the customer when the system specifications were drafted.

  Similarly, just as it is possible to feed real numerical data into the model, data recorded in flight from onboard sensors can be injected into the system's digital processing units.

  The last example is about controlling antenna radiation and decoupling between antennas.

  To meet this requirement and also to avoid long and costly in-flight evaluation programs to gauge jamming or jamming detection performance, Thomson-CSF set up a special platform at its Le Mengam site near Brest in Brittany.

One of the main uses of this platform has been to validate the simulation tools mentioned earlier, including SARGASSES. But for customers, it is also a less uncertain and more comprehensive benchmark for system acceptance than in-flight testing can be.

Modeling techniques now offer such high quality and reliability that Le Mengam platform is only used part of the time. It is available to any company or organization that wishes to use it and that can work there totally independently.

5. MONITORING AND DEMONSTRATING OPERATIONAL PERFORMANCE ON THE GROUND (CHART 22)

The purpose of the tools we have looked at so far is basically technical, even if we correlate the technical measurements with clearly defined operational objectives whenever this is possible.

However, the operational performance of an onboard system cannot be fully and convincingly monitored and demonstrated on the ground for the customer, unless the dynamic behaviour of the aircraft can be taken into account.

This is why Thomson-CSF set up a dynamic testing centre for onboard equipment and systems in the facility set aside for this purpose by the French defence procurement agency at the Brétigny test range near Paris.

The centre has an anechoic chamber, a mobile platform and a radiating wall that can simulate transmitters in a broad range of frequencies, as well as radar targets. The Brétigny centre is presented in the video.

This centre has been extremely valuable and made substantial savings in test flight hours when evaluating multi-target combat modes for fire control radars. It can also be used to evaluate aircraft self-protection systems, and an optronic source module is currently being designed.

These examples have shown what can be done on the ground to overcome risks on airborne programs and to keep in-flight development testing to a strict minimum.

(VIDEO ON METRO, LE MENGAM, BRETIGNY)

This presentation (chart 23) has covered the main stages in the industrial process of integrating an onboard system. The real life of the system, its operational life, begins at the end of this process.

The same tools as were used to define the system will now help to train operators to program the system (threat identification and jamming/deception libraries, for example).

They will also be used throughout the system life cycle to interpret new situations and propose improvements where possible.

This permanent dialogue with the people who use the system that is finally delivered is extremely important. It not only enables us to validate the whole of the industrial process by seeing what happens in real operational conditions—the only conditions that ultimately matter—but also makes us better prepared to cope with future systems.

Substantial industrial resources are therefore needed to define, integrate and support onboard systems, and those resources need to be utilized as fully as possible and developed on a permanent basis. These industrial assets in turn rely on the even more substantial resources of government research and testing establishments.

Until now, France has managed to set up most of these resources itself. During successive programs, close ties have been forged between manufacturers of airframes, engines and electronic systems, and between industries, government bodies and customers.

Today, however, reductions in defence spending and the increasing complexity and cost of these systems mean that major European players need to work even more closely together and to pool the resources that they have at their disposal (chart 24).

Some concrete examples can be given :

a) The AMSAR program of future airborne program between Thomson in France, GEC in the United Kingdom and Dasa in Germany is an example of how successful this kind of cooperation can be. It was successful because resources and experience were shared effectively and duplication of efforts was avoided. Above all, it was successful because of the quality of the relationships that grew up between the different teams involved.

b) Another example is within reach of the Europeans and concerns system integration more directly. This is the modular avionics concept for combat aircraft. In this area, the United Kingdom, Germany and France have defined their objectives and configured their respective industries. In France, a formal 50-50 partnership (GIE) has been set up between Dassault Aviation and Thomson-CSF to conduct a program of this kind with European partners.

c) The digital processing market changes very quickly, and it is now possible to adopt a very open approach to architectures, based on the use of commercial off-the-shelf software and aiming above all at achieving greater reusability of application software as hardware performance improves.

d) THOMSON and ELETTRONICA in Italy have decided to cooperate, THOMSON having taken a 33% share in the capital of ELETTRONICA, so far . This strategic alliance definitely stregthens the two companies' leadership in the domain of Electronic Warfare. Not only can we address a broader market, which is the commercial and marketing asset of this alliance, but also can we specialize each company in its better skill for such line of products, which is the industrial and technical asset of this alliance.

* *

For decades of experience in Defence systems and thanks to the subsequent tools which have just been presented in this lecture, THOMSON has combined the need of high level of performance with affordable costs, both for our customers' satisfaction.

Now, the times have come when we also have as smartly as possible to combine the strengths of European companies with ours. We have begun to follow this strategic path, still with the final objective of our customers' satisfaction, but also of the survival of our high skill and high added-value activity, hopefully.

Finally, strategic management of the cost issue is not less than to address this fascinating spectrum of our companies' skill, starting from the deepest scientific and technical knowledge to the combination of know-how and cultural behaviours of partner companies, having to cooperate in a closer and closer way.

-- Septembre 1997 --

THOMSON-CSF Radar & Contre-Mesures
AREAS OF ACTIVITIES

- SINCE MORE THAN 30 YEARS, A MAJOR COMPANY IN THE DOMAINS OF :
  - AIRBORNE RADARS
  - ELECTRONIC WARFARE & INTELLIGENCE
  - AIRBORNE SYSTEMS
- IN SERVICE OF FRENCH FORCES AND OF MORE THAN 40 COUNTRIES WORLDWIDE

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CHART 1

Airborne self - protection systems

MSPS
SUPER-ETENDARD - C160

EWS
NH 90 (TTH)

TWE
TIGRE

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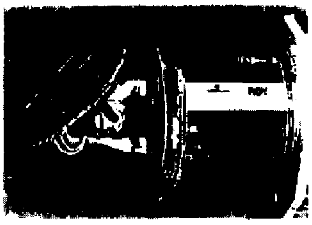
CHART 2

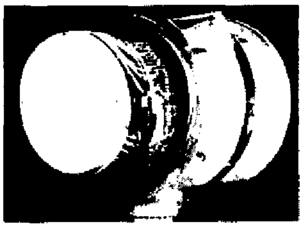
Airborne Combat Radar and self - protection Systems

ICMS
MIRAGE 2000



RDY

SPECTRA
RAFALE



RBE2

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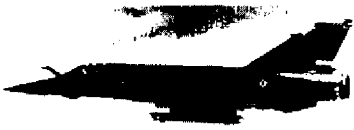
CHART 3

ELINT Systems



F1 CR

F4 EJ

F16

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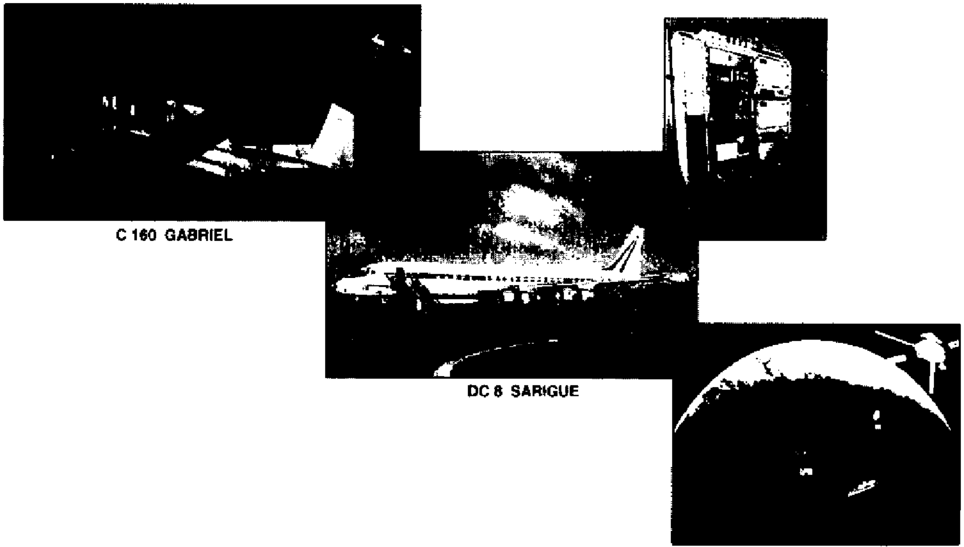
CHART 4

SIGINT Systems



C 160 GABRIEL

DC 8 SARIGUE

SPACE APPLICATION

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CHART 5

Airborne programs and systems

MIRAGE F1 - SPAIN

AMASCOS

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CHART 6

Airborne System Integration

CONDITIONS TO THE SUCCESS

- PERFECT UNDERSTANDING OF THE CUSTOMER'S REQUIREMENTS AND EXPECTATIONS
- AGREEMENT ON THE SOLUTIONS CHOSEN TO MATCH THE REQUIREMENT
- AGREEMENT ON THE TEST AND EVALUATION PROCESS
- CONTINUOUS TIGHT CONTROL OF THE RISKS DURING THE DEVELOPMENT PHASE OF THE SYSTEM
- SUPPORT OF THE CUSTOMER ALL ALONG THE OPERATIONAL LIFE OF THE SYSTEM

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CHART 7

Airborne System Integration

METHODOLOGY AND ADAPTED TOOLS FOR

A CUSTOMER REQUIREMENTS [illegible]

B RISK MINIMIZATION

C TECHNICAL PERFORMANCES VALIDATION

D OPERATIONAL PERFORMANCES DEMONSTRATION

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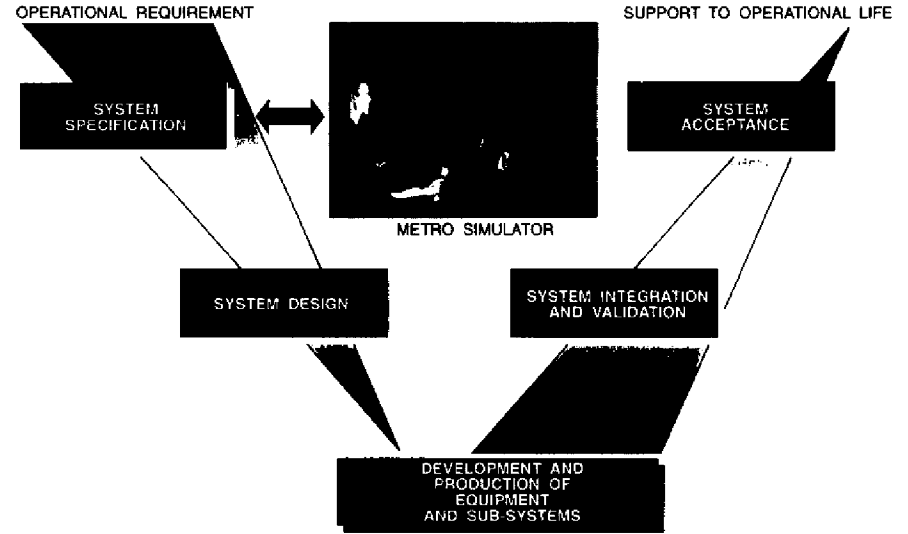
CHART 8

STEP 1 - Understanding the requirement



OPERATIONAL REQUIREMENT

SUPPORT TO OPERATIONAL LIFE

SYSTEM SPECIFICATION

METRO SIMULATOR

SYSTEM ACCEPTANCE

SYSTEM DESIGN

SYSTEM INTEGRATION AND VALIDATION

DEVELOPMENT AND PRODUCTION OF EQUIPMENT AND SUB-SYSTEMS

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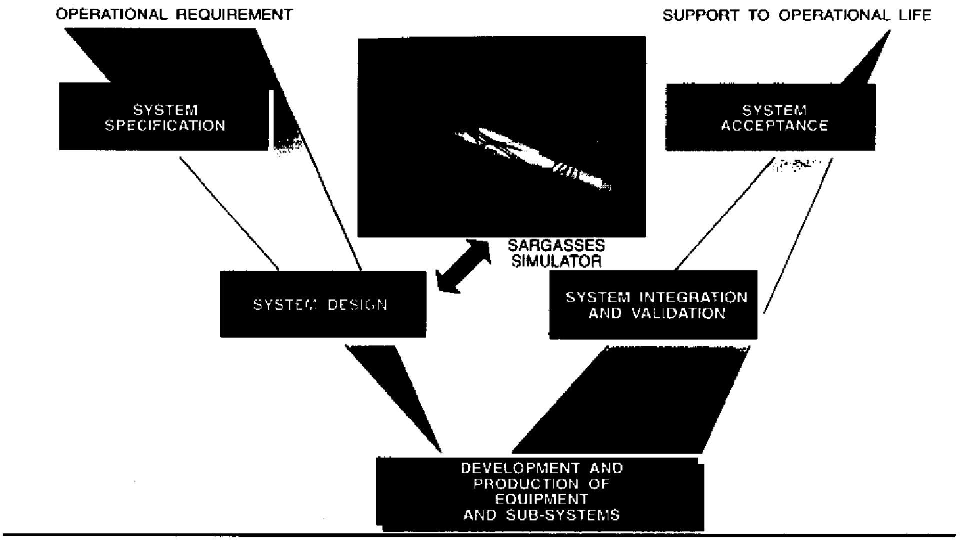
CHART 9

STEP 2 - System Design



OPERATIONAL REQUIREMENT

SUPPORT TO OPERATIONAL LIFE

SYSTEM SPECIFICATION

SARGASSES SIMULATOR

SYSTEM ACCEPTANCE

SYSTEM DESIGN

SYSTEM INTEGRATION AND VALIDATION

DEVELOPMENT AND PRODUCTION OF EQUIPMENT AND SUB-SYSTEMS

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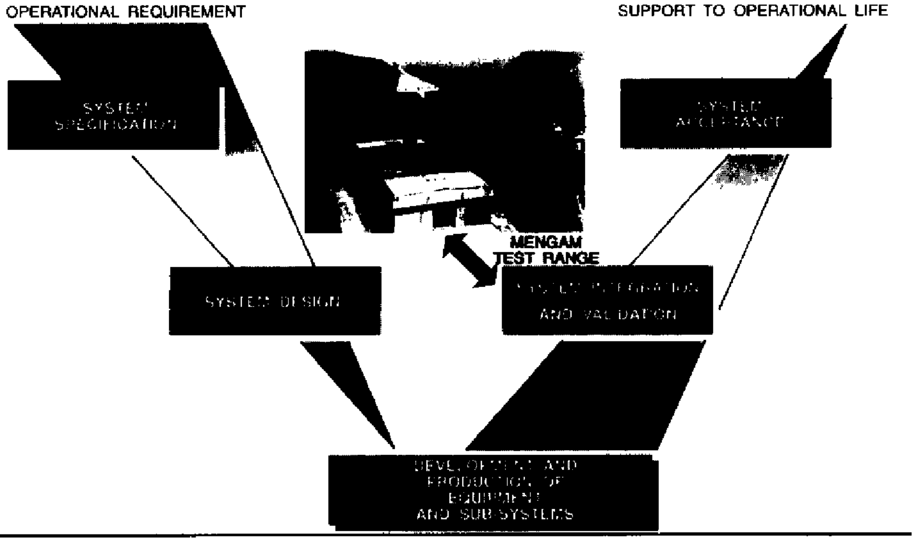
CHART 10

STEP 3 - Technical performance validation



OPERATIONAL REQUIREMENT

SUPPORT TO OPERATIONAL LIFE

SYSTEM SPECIFICATION

SYSTEM ACCEPTANCE

MENGAM TEST RANGE

SYSTEM DESIGN

SYSTEM INTEGRATION AND VALIDATION

DEVELOPMENT AND PRODUCTION OF EQUIPMENT AND SUB SYSTEMS

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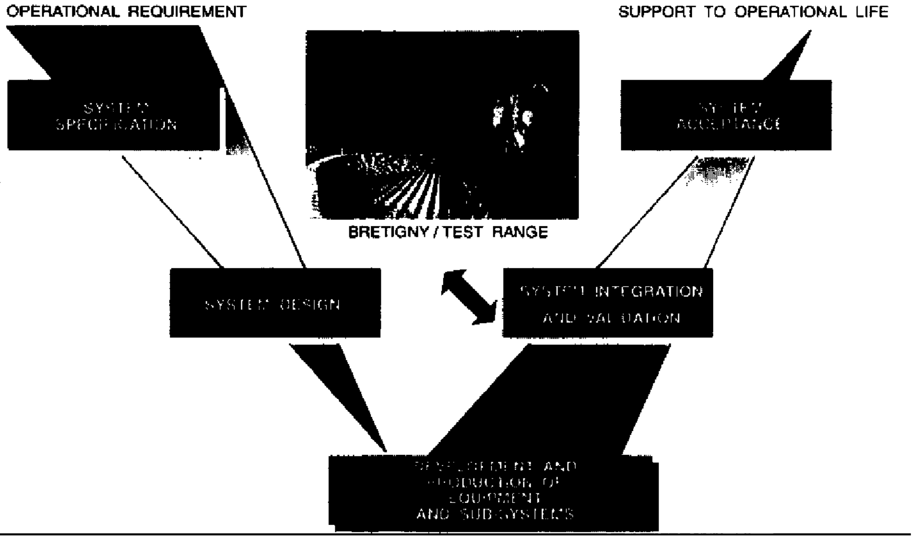
CHART 11

STEP 4 - Ground performance validation



OPERATIONAL REQUIREMENT

SUPPORT TO OPERATIONAL LIFE

SYSTEM SPECIFICATION

SYSTEM ACCEPTANCE

BRETIGNY / TEST RANGE

SYSTEM DESIGN

SYSTEM INTEGRATION AND VALIDATION

DEVELOPMENT AND PRODUCTION OF EQUIPMENT AND SUB SYSTEMS

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CHART 12

STEP 1 - Requirement Understanding

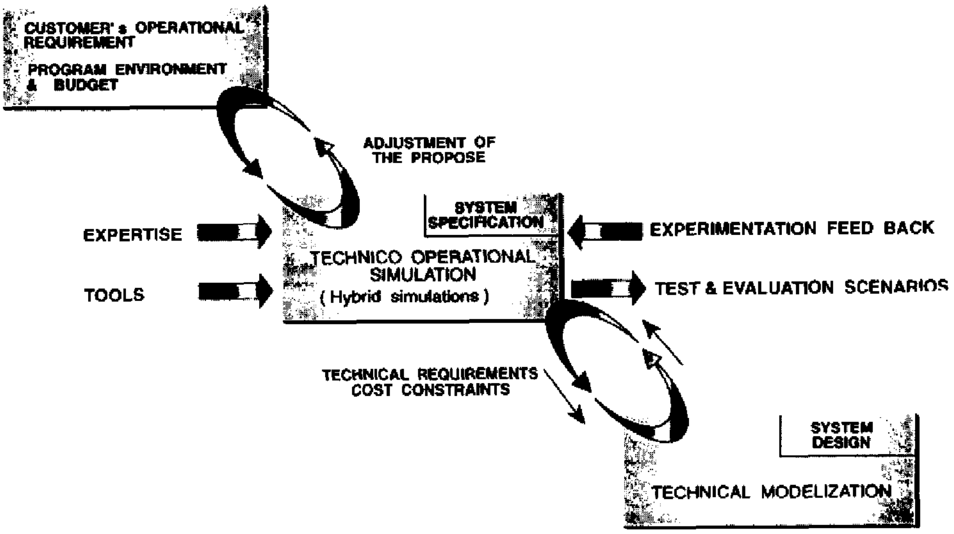

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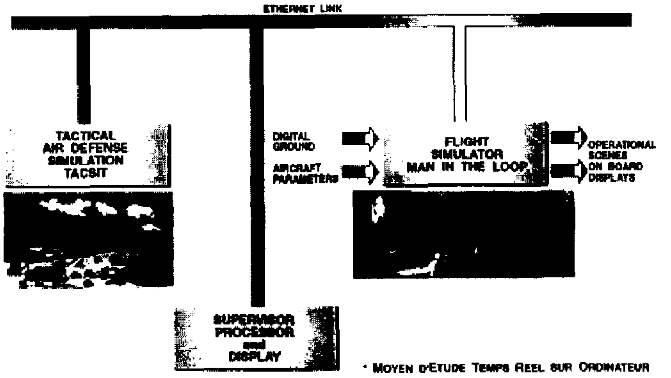
CHART 13

METRO* : Distributed Interactive Simulation



* Moyen d'Etude Temps Reel sur Ordinateur

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CHART 14

STEP 2 - Risk evaluation

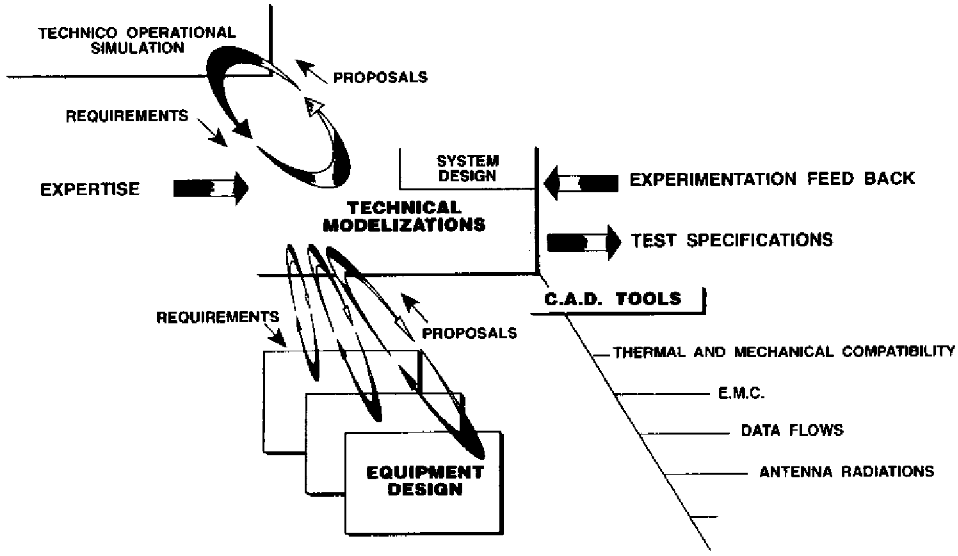

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CHART 15

Environmental simulation

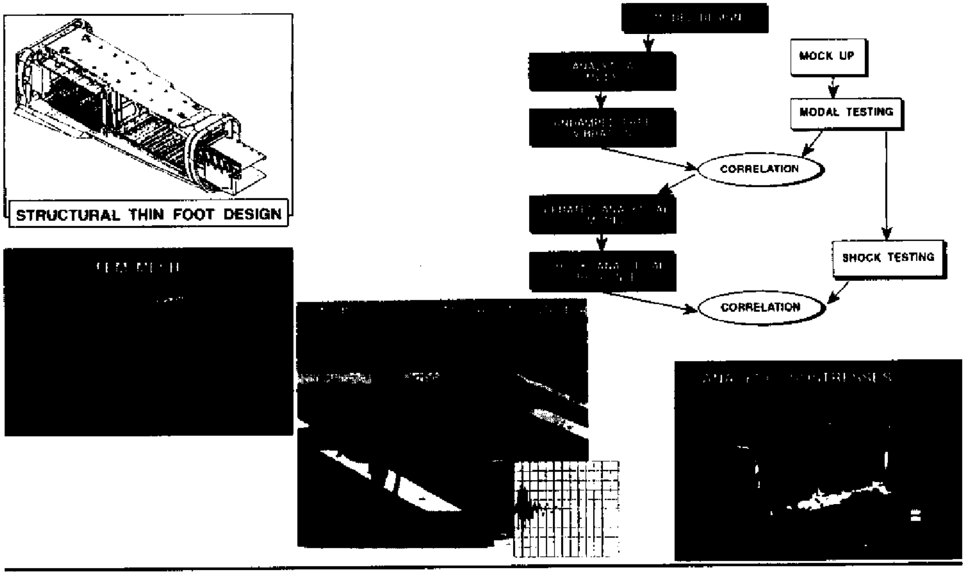

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CHART 16

Evolution of Electronics Part in Aircraft Systems

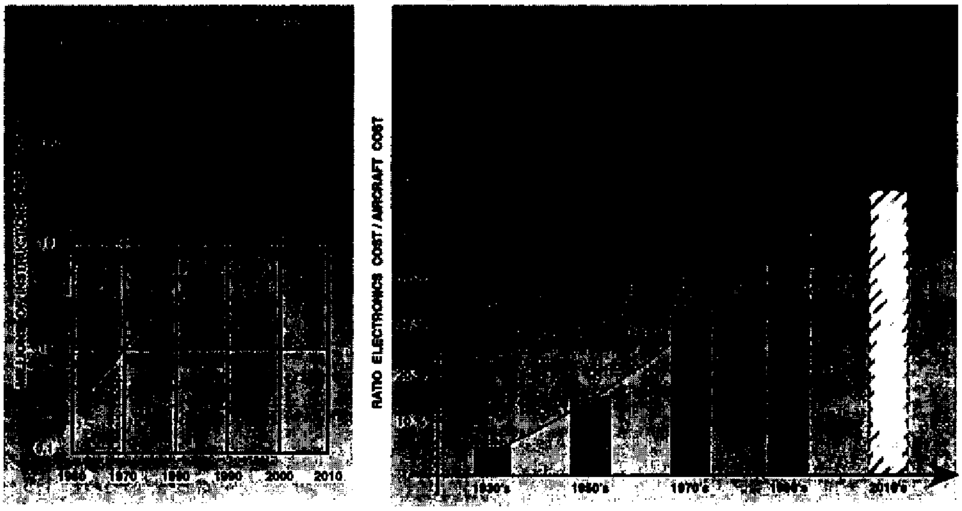

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CHART 17

ICMS 2000

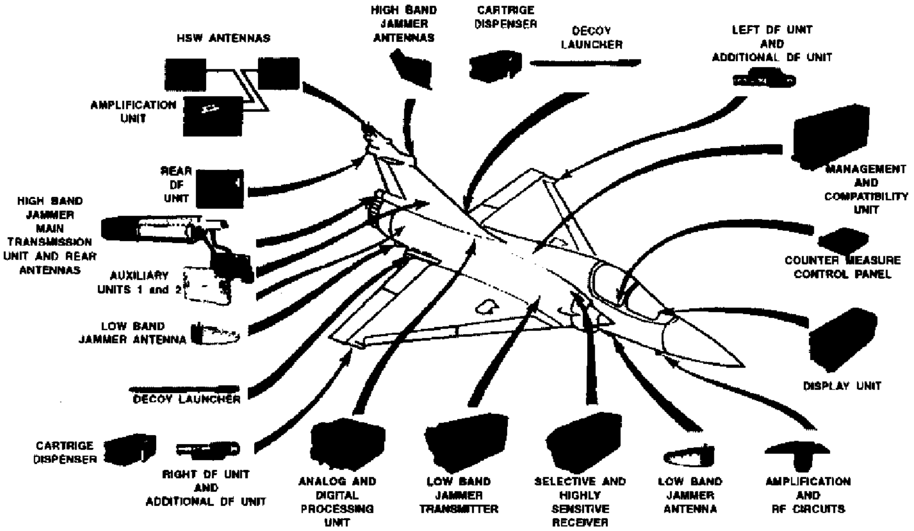

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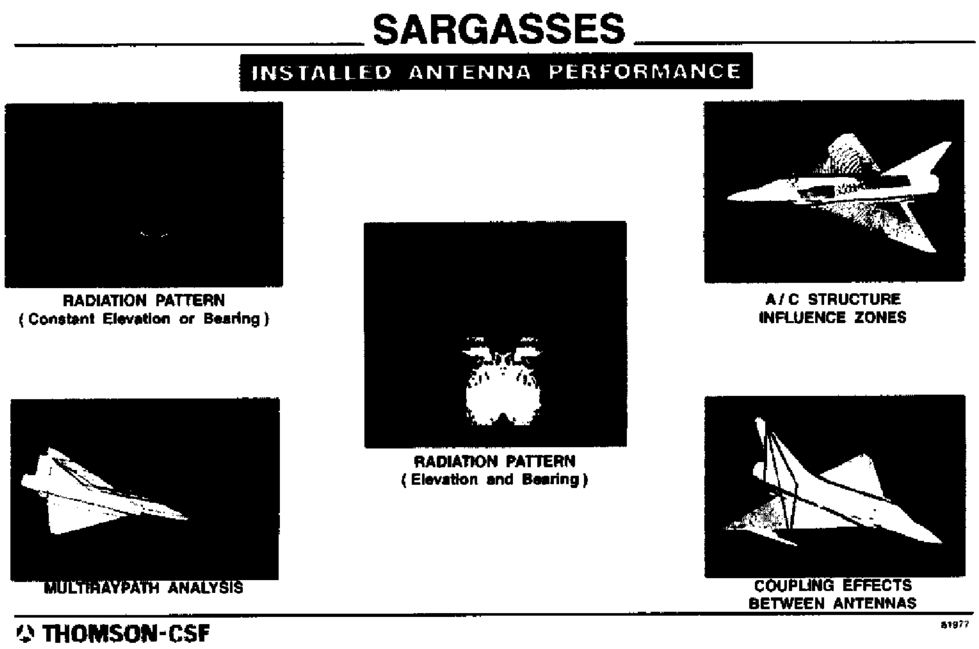
CHART 18



SARGASSES

INSTALLED ANTENNA PERFORMANCE

RADIATION PATTERN
(Constant Elevation or Bearing)

RADIATION PATTERN
(Elevation and Bearing)

A / C STRUCTURE
INFLUENCE ZONES

MULTIRAYPATH ANALYSIS

COUPLING EFFECTS
BETWEEN ANTENNAS

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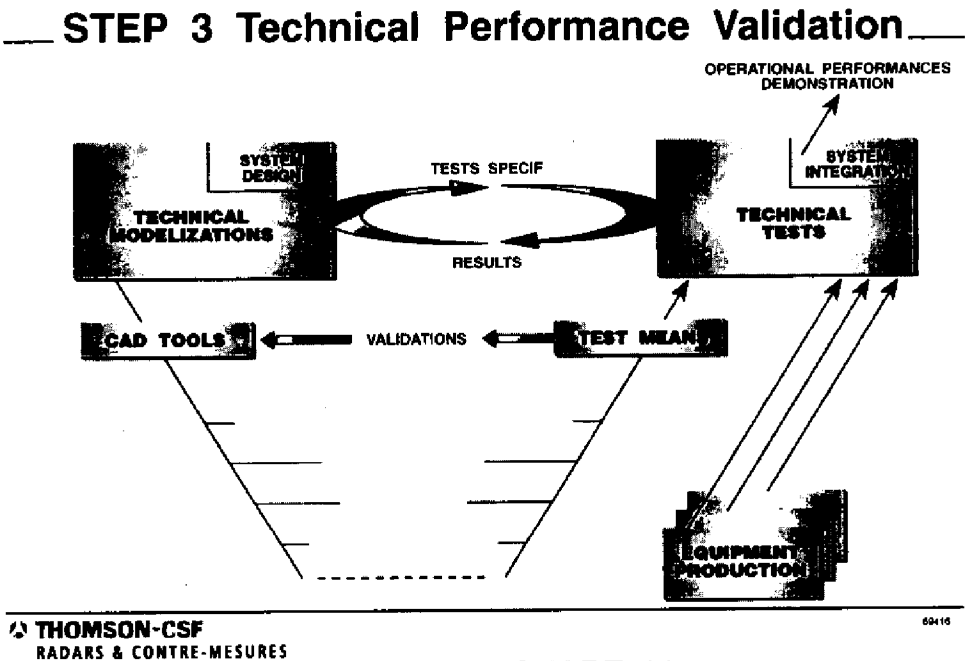
CHART 19



STEP 3 Technical Performance Validation

OPERATIONAL PERFORMANCES
DEMONSTRATION

SYSTEM DESIGN

TECHNICAL MODELIZATIONS

TESTS SPECIF

RESULTS

SYSTEM INTEGRATION

TECHNICAL TESTS

CAD TOOLS

VALIDATIONS

TEST MEANS

EQUIPMENT PRODUCTION

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CHART 20

ICMS test bench

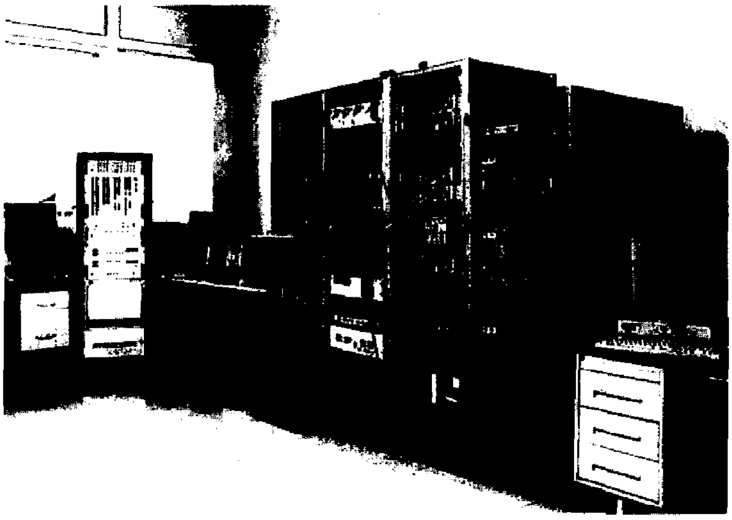

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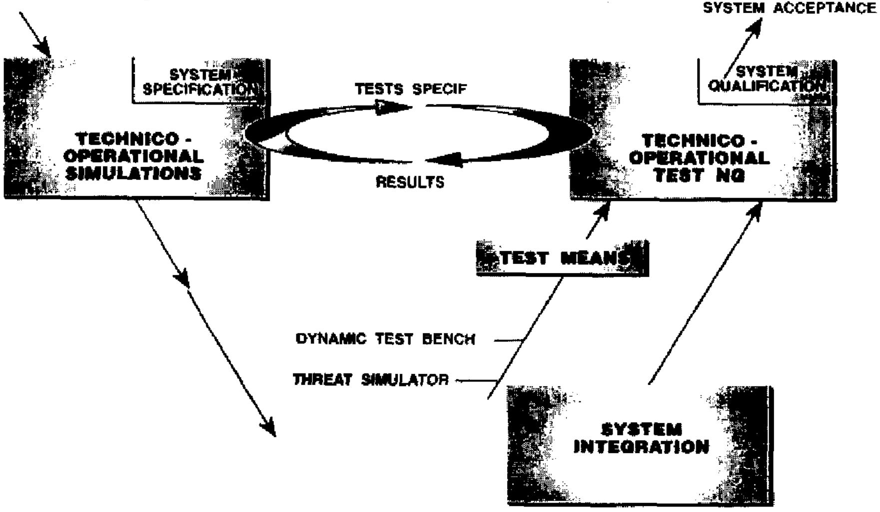
CHART 21

STEP 4 : on ground operational performance demonstration



IN FLIGHT TESTS
SYSTEM ACCEPTANCE

SYSTEM SPECIFICATION

TECHNICO - OPERATIONAL SIMULATIONS

TESTS SPECIF

RESULTS

SYSTEM QUALIFICATION

TECHNICO - OPERATIONAL TEST NQ

TEST MEANS

DYNAMIC TEST BENCH

THREAT SIMULATOR

SYSTEM INTEGRATION

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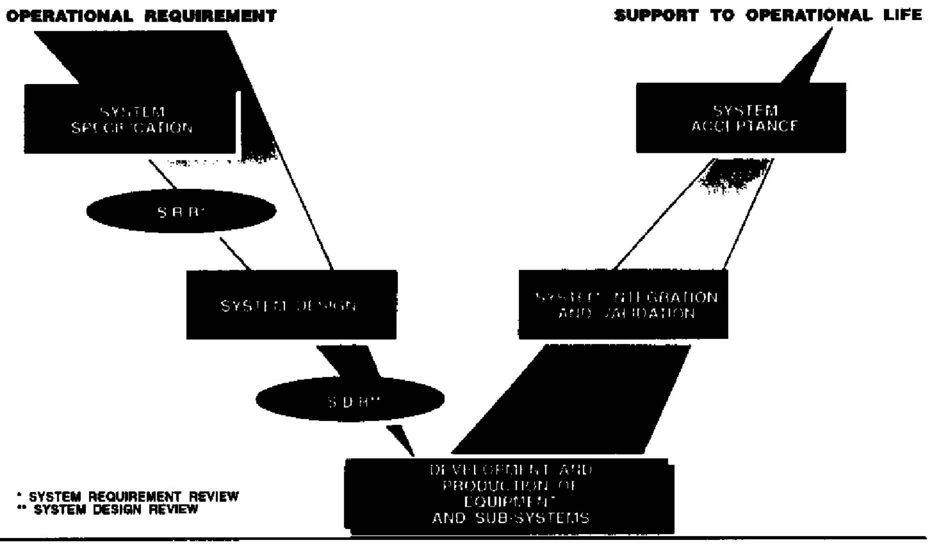
CHART 22

Typical System Life Cycle



* SYSTEM REQUIREMENT REVIEW
** SYSTEM DESIGN REVIEW

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CHART 23

Airborne System Integration

- A MATTER OF COOPERATIONS
  - COOPERATION WITH GOVERNMENT ESTABLISHMENTS
  - COOPERATION WITH AIRCRAFT MANUFACTURERS
  - COOPERATION WITH ELECTRONICS COMPANIES
- BESIDES TECHNICAL AND PROGRAM MANAGEMENT SKILL, COSTS WILL ALSO BE DRIVEN BY THE ABILITY TO COOPERATE WITH PARTNERS

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CHART 24