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Engineering Aspects of International Cooperation in Aeronautics

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Abstract

Based on direct experience of leading a large, transnational, aerospace programme, the author discusses the broad subject of international cooperation and, in particular, the ways in which complex engineering functions can be organised in a consortium to bring benefits which might not be achievable in a single partner activity. Suggestions are given concerning the coordination of technology acquisition, when various Government and industrial partners are involved. Organisation approaches necessary to compensate the differences in national characteristics and language are considered. The clear assignment of responsibility within the consortium structure is paramount, and an example of how this can be made to work is given. The challenge and potential rewards are high and the aims are worth pursuing for the benefit of all.

I. Introduction

Engineering considerations have seldom been the initial or motivating factors in the build up of international cooperation. But, as soon as such cooperation starts to develop, the engineering aspects play an essential role in its success.

The continuously growing need for efficiency, safety, performance, comfort, durability, ... etc, that characterizes the progress of aeronautics leads to ever increasing engineering requirements and activities in all concerned fields, from basic research to production processes. Scientists and engineers educated and experienced in one or several aspects of aeronautics do exist in different countries of the World, and it normally could be expected that the natural behaviour for a "promoter" of any aeronautical development would be to try to put together the available resources on an international basis. Why is real life so different and why is international cooperation in engineering generally a consequential aspect of a decision to work together taken for other reasons ? In my opinion, there are three main reasons :

1. First, nationalist or chauvinist behaviour still remains too common, either because of the "competition oriented" environment in which we live, or because it is difficult to know and consider what happens outside one's local or national "club". It is psychologically difficult to recognize that someone else can or could do as well as, or better than, you can and it seems that this difficulty is greater for groups than for individuals (The N.I.H. "Not Invented Here" syndrome).

2. Second, there is no "yardstick" to measure the value of engineering contributions -essentially intellectual- to a common task. Only the "products" resulting from the engineering efforts have a "market" or "profit" value, but it cannot be related precisely to the several engineering contributions they include. In a commercial environment, there is a tendency to do everything possible in one's group, to avoid being accused of "giving away" valuable knowledge or experience.

3. Third, engineering work in cooperation between groups living and working in different countries, often not speaking usually the same language, is basically difficult to manage efficiently. Nobody likes to consider difficult solutions as long as easier ones are available. And basically groups of engineers think that -if they were given the required resources- they can do themselves whatever is required. It often happens that the less they know, the less they see the difficulties.

Nevertheless, international cooperation has become mandatory for other reasons -to start with, the mere lack of convenient resources on a national basis- and joint engineering teams have had to find, test and implement the proper solutions.

Neither the contribution of European scientists to the nuclear effort of the United States during World War Two, nor the work of the various German engineering teams transferred into the victorious countries immediately after*, nor even the increasingly common sub-contracting or licencing activities,can properly

* Like the "rocket" specialists with Wernher von Braun in the USA, the jet engine specialists of Dr. Oestrich in France or the teams "deported" to the USSR.

be considered as "international cooperation". European countries (France, Great Britain, Germany, Holland) with important aeronautical tradition and limited resources have, as one could expect, been specially and early motivated for effective international cooperation. Some requirements of their Defense equipment have been selected for this purpose, like the Franco-German Transall in 1958 and the Franco-German-Dutch Atlantic in 1959. Many others have followed, for example "Government controlled" programmes like the military ones, the space activities, and the "Concorde", or "market oriented" products like the commercial aircraft Airbus line.

The United States of America, having enough resources to do alone what they want, have *not* been very active in this respect, but are finally moving in a similar manner for the development of new commercial engines, like the Franco-US CFM-56 and the IAE 2500 (Pratt and Whitney, Rolls-Royce, Fiat, MTU, Japanese Industry). The importance of engineering in these cooperations, and especially in those which are exposed to open and wild competition -like commercial aircraft and engines or satellite launchers- is the result of the existing competitive environment in aeronautics, where only the "best" products can survive.

In these cases the cooperative engineering tasks cannot be limited to the proper definition of a "good" product, but must lead to an "outstanding" product, developed and produced at competitive costs and perfectly matched to the market demands.

II. Cooperation in basic technology acquisition

Engineering starts with the acquisition of basic technology, that is the scientific understanding of all elements required to develop the product. In an "open" scientific and commercial world, like the world of "western countries", all basic technologies that are or have been used are very quickly known, even if it is sometimes possible, for a limited period, to keep control of some "tricks" useful for practical applications. But because, in the aerospace field, success requires progress, our future is continuously dependent on the continuing acquisition of improved or new basic technologies. Very large sums are then spent for this purpose, both by the Governments and by the industry. It is clear that, today, there is a tremendous wastage of resources because of the duplication or triplication of research efforts, and that cooperation could significantly reduce the total expenditures or increase the results.

The ideal solution would be that, between friendly countries, or groups that can be friendly even if they compete against each other, efforts should be coordinated to avoid unnecessary duplications and to concentrate resources on some more important aspects. This would require a process similar to that necessary for cooperation on a "given product", that is :

- Target definition - in this case acquisition of basic technologies for a wide range of applications.

- "Work-sharing" and coordination.

- Proper exchange of data for applications.

Formidable obstacles still remain to such an approach, for example :

- The links (sometimes excessive) seen between these technological achievements and national security.

- The fear to "help" a real or potential competitor.

- The usual misjudgement on the relatively "high" value of someone's contribution compared to the "low" value of what others bring.

- The attractiveness of some "glamorous" fields of research in which everybody wants to participate.

- The "defensive" habits of some research groups who try through legal actions (patent claims), to get money from the industries of other countries for ideas* that they are the only ones to think "original", making then the fortunes of lawyers without any scientific or technological result.

Nevertheless, progress in the right direction is possible, starting with cooperation between limited groups of countries or industries. Some European countries have shown the way, either at Government' level, like common research centers (Institut Franco-Allemand de St. Louis) space research centers, or at industry level (AICMA wind tunnels).

But these are only "starting" steps, and wide further developments are required.

I would like to use this opportunity to make two suggestions :

a) That the Governments of those countries that have several "product" cooperations ask their state supported research organisations to prepare a large scale coordination of activities and exchange of results between these organisations. This must be obtained through a very light structure and not by creating

* For example the NASA claims about the "so-called" supercritical wings.

a "new" common research group that will take too much time and eventually add to the relative inefficiencies.

b) That the industries already cooperating on "products" coordinate completely their own efforts, for example with the help of the coordinating bodies already established for the products themselves. To some extent, and given the existing links and influence between the national industries and the corresponding "official" research centers, this could lead in practice to the pragmatic coordination/cooperation looked for in the first suggestion.

A key condition to the success of such approaches is a clear and open agreement on the use of results. No cooperation can work if a partner tries to "retain" his contribution or to make it available only "in exchange for" a contribution of similar short term value from the other partners. Everyone must take the risk of being a "net contributor" in the short term and reaping benefits from the cooperation in the long term. Once more a difficulty results from the natural tendency to "overestimate" his own contribution.

Practical tools are then patent/licencing exchange agreements and programme exchanges. Of course, commitments must be made to avoid unilateral restrictions or embargoes.

III. Product engineering adaptation to the typical cooperation schemes

There are classically three cooperation schemes :

"Committee management"
"Prime/sub-contractor system"
"Management group"

Experience has confirmed that "committee" management is totally inadequate for engineering purposes. If it is eventually possible for a committee to agree "where to go", it is very difficult to decide "how", in face of the conflicting experiences or opinions. Engineering requires continuous practical decisions, implying inevitably risks and responsibilities. For success, these decisions cannot be "compromises", but must be the "best ones". And all elements for a comprehensive objectivity are generally not there, leaving a substantial part for subjective judgements. When the participating members of a committee are the undisputed and fully powered leaders of their industries, there is some hope of reaching agreements, but that can be found only for exceptionnally important basic decisions ("summit" meetings). In daily life, there is the continuous risk for the committee members to be criticized -or even disavowed- if they do not "stick" to their own company position.This obliges them -when they agree on somebody else's position- to explain and convince their own organisation- that is at least a lengthy process. To put it clearly, there must be an"architect".

The "prime/sub-contractor" system is a simple and effective tool of management. It concentrates the decision powers in the "prime" partner, the others -even if they share the risks- accepting to comply with the "prime" instructions and to a large extent limiting their activities to their own contractual share of the work.

It is not fully a "cooperation", but rather a participation with limited responsibility.

I do not feel that such a scheme requires any more comments, because it is only an extension of the usual practice in the aerospace industry, where since decades, in all countries, all companies are using sub-contractors to avoid unnecessary peaks and troughs in the utilisation of their resources.

The scheme in which "equal" partners cooperate together in all aspects of the common task, whilst avoiding the inefficiencies and risks of the "committee" system is what I call the "Management group".

Its main characteristic is that a special group is created -with men that are not any more responsible to any specific partner- to manage all the activities as a "prime" contractor usually does. To insure that this happens in a proper legal form, a specific management company is generally established (Airbus Industrie, Euromissile,...).

As far as engineering is concerned, this system implies the presence within the group of engineering leaders (Technical Director, Chief Engineer,...) with the proper staff to analyse, prepare and participate in the decision process.

An essential element is related to the management responsibilities. In all cases, there is a "customer" (Government, airline, ...) that demands a responsible counterpart-"the manufacturer". And engineering aspects are absolutely essential in this respect, because they control the practical and legal possibilities to use the products effectively (reliability, safety, performance, certification,...).

From an engineering point of view, the essential problem in a cooperative venture is to make the best use of all capacities, experience and talents available, whilst managing the entire development in an effective and orderly manner.

The only way to make use of all talents available is to involve them in the maximum number of aspects of the common task. "Participation" is then the name of the game, and each and every "participant" must feel the duty and be given the possibilities of expressing his opinion, in proposals and/or constructive criticisms, not only in relation to "common" tasks, but also with regard to those tasks that are under the responsibility of the other participating partners. Mutual early information is then essential, and important aspects must be "discussed".

Effective and orderly management implies the existence of a "decision maker", whose task is to select the "best" solution after having looked at all partners' proposals, opinions and judgements.

This decision maker must show :

Initiative : To put on the table the maximum number of significant aspects and to propose lines of discussion.

Objectivity : To carry out the decision selection job as efficiently as possible and with the maximum use of factual aspects.

Persuasion : To convince all participating partners that the decision taken -even if not the one they would have liked- is the best for the programme.

Convinced participants always do a much better job than those who do it only by straight discipline.

This is a century old experience, that can be illustrated by the story reported in China several centuries before Christ : "Once upon a time, three competing "Warlords" met on the edge of a torrential river, swollen by recent heavy rains, whose banks were steep and slippery. To some extent fed up with their classical fights, they decide to organise a contest of the qualities of their armed forces, beginning with "discipline". The first Warlord, who boasted the more about his strength of command, proposed to the two others to cross the river over a frail rope bridge, with a few servants, whilst a battalion of each of their body guards came to attention in rows of ten, facing the river. Comfortably installed with drinks on the other side, the Warlords started the contest. The first shouted "Parade march, forward", and his battalion moved towards the river, each rank falling in the whirling waters one after the other as soon as they reached the edge of the bank. A few minutes later, they were all drowned. The second Warlord, who was not sure to obtain such unconditional obedience, sent to his troops a messenger with "written and sealed" orders, and his battalion perished like the first.

The third Warlord there asked permission to go and talk to his soldiers, then came back and, as soon as he sat with the other Lords, the remaining battalion began to move. As soon as each rank reached the edge, the guards threw off their shields, armors, heavy weapons, clothes, keeping only a light dagger. Then a significant number of them was able to reach the opposite bank, to climb it and there, daggers out, to surround the three Lordships.

Then the third Warlord said politely to his colleagues : "Sorry, you are now my prisoners and hostages, and it is simple justice, because you have forgotten that it is by explaining your strategy and targets to the executants that you get the best results".

This is why I like to insist on "management by persuasion".

IV. People, language, organisation

One of the essential aspects in international cooperation, and specifically in engineering, is related to people engaged in these activities at all levels of responsibility and competence.

By nature, the participants who have to work together, have been educated in different countries and environments, and as a consequence have their own character and particularities. Differences in respect of professional training, the approach to problems, reactions to events, management procedures etc... are significant. To these can be added the problems arising from living and working in a foreign environment for a large proportion of the people involved, and language as well remain a problem.

These differences must be made positive. If proper and open exchanges of views are not only made possible, but systematically organised, it is possible to increase the engineering quality and reduce significantly the risk of errors. Looking at a problem with different eyes and from different points of view enable it to be understood more completely and allow better solutions to be found. It is some sort of a "self-checking" system. People involved in such processes must be flexible, ready to adapt, comprehensive and prepared to integrate. In addition to using their professional qualifications they must demonstrate a readiness for patiently doing a very hard job.

Today, neither the formal education system nor normal company training tries to prepare people in this art. We just expose them to the cooperative world and leave it to the individuals to either find their way or drop out.

The effective existence of significant international cooperation makes now a more systematic training possible, and some of the competence in this field, built up in the past years, could usefully be made available to complement the training systems of our aeronautical engineers and technicians.

Of course, nothing can be done without a proper vehicular language, to enable direct and quick communication. Despite all the retarding influences of national chauvinisms, there is no choice left than to use English, or more precisely anglo-american aerospace language, with special attention given to spell out things clearly and simply, because not everyone can be equally skilled in his use of the language. Less can be left to implication and innuendo,and hence to chance. It is very important in cooperative programmes to follow the basic technical language rule that each word must be used in a specific signification and that each concept must be always expressed with the same words (contrary to the usual rules of "good style", as pinpointed for example in French language). Even if repetition looks boring, it is better than confusion.

Basic standards, units, rules, processes, specifications must be made common, or equivalences must be settled from the start. To a large extent, they are "part" of the communication language. Significant progress remains necessary in this respect, despite the large adaptations already achieved in the development of specific programmes. It would be useful to strongly coordinate all official actions to standardise those elements at every occasion, and continuous and intensive push by Governments in this direction will be beneficial for all.

The details of engineering organisation are also very important. Pragmatism has to be the rule of the game, to make the best use of the existing situations. One must remember that cooperation takes place between already existing and organised groups, and that they cannot be easily or quickly changed.

In the reference scheme of the "management group" this group must have clear and unmultiplicated links with the corresponding partner organisations. This is sometimes delicate, as the basic tasks of this group and those of the partners are not entirely comparable and since partners do not necessarily have identical organisations.

Clear cut responsibilities are essential. The management group has the overall responsibility for the product(s). Beyond this it is interesting that partners have the design responsibility for the components allocated to them for manufacturing within the frame of the general work-sharing agreement.

From an engineering point of view a three level responsibility system for what we call non specific design (engineering and development) work, has demonstrated its practicability.

<u>Level 1</u> (overall responsibility) covers essentially :

- Basic design principles and instructions, aircraft specifications.

- Definition of tasks, systems specifications.

- Data collection and assessement.

- Tests on complete systems.

<u>Level 2</u> (partial responsibility) covers essentially :

- Execution of tasks defined on level 1.

- Preparation of all data necessary for design and airworthiness for level 1 responsible.

- Equipment technical specifications.

- Partial testing.

- Equipment purchasing and procurement.

<u>Level 3</u> (collaboration) : As agreed upon on request of the level 1 or of one of the level 2 responsibles.

Some examples from an aircraft programme (A320) :

- Aircraft design configuration, engineering philosophy including design targets and technical project management. Level 1 and Level 2 - M.G.* ; Level 3 - Partners.

- General design instructions, guidelines, design standards (structures and systems).
Level 1 - M.G. ; Level 2 - Partners.

- Aerodynamics - Follow-up of results and progress, checking of compliance and coordination of work for aircraft definitions : Level 1 and Level 2 - M.G. ; Level 3 - Partners.

- Wing : Level 1 - Partner B.
High speed wing aerodynamics : Level 1 - B ; Level 2 - B
Low speed wing aerodynamics : Level 1 - B ; Level 2 - D
Wing/engine pod interaction : Level 1 - B ; Level 2 - A.

- Aerodynamics rear fuselage and tail surfaces : Level 1 and Level 2 - D.

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* M.G. = Management Group.

- Nacelle aerodynamics and installed engine performance : Level 1 - A ; Level 2 - A.

- Aerodynamics data management : Level 1 - A ; Level 2 - Partners in specific areas.

- Weight and balance calculation and management : Level 1 - M.G. ; Level 2 - A, B, D for their share.

V. Economical aspects

Economical aspects play a strong motivating role in international cooperation.

In the first attempts after World War II, the essential reasons for cooperation were the sharing of costs and investments that were too high for a single partner, as well as the extension of the "market", leading to higher production rates and quantities, and hence to lower costs, thanks to the classical "learning curve" effect.

It was then generally accepted that "engineering" will cost significantly more than for a "single company" programme, because of the unavoidable problems of communication, understanding and duplications. Simultaneously, it was also considered that the development will take more time.

The experience gained, the adaptation of the usually cooperating partners to this "way of life", and the pragmatic settling of convenient organisation schemes have now created (at least in Europe) a situation where -even on the engineering aspects- cooperative ventures make direct economic sense.

This results from three factors :

- Convenient organisation and education of involved people, minimizing the additional expenses and delays necessary to do work "together" on an international basis.

- Specialisation effects that show immediate positive effects when several programmes are done by the same group of partners, in the proper sequence, provided the psychological tendency to oppose "specialisation" is properly fought (as it is in the case of the Airbus programmes).

- Definite capability of a "fully cooperating" system to reduce errors or mistakes through the continuous cross-checking of activities. This very important advantage of cooperation -of which several clear proofs have appeared in the course of Airbus developments- is impossible to quantify at the beginning, when programme economics are prepared for an eventual decision. But it does exist -and it is very important. The mere fact that programmes are executed on time and on cost is proof of the validity of the concept.

Another positive aspect results from the ease of exchange of experience and "tricks" in a cooperative system. If properly motivated, the participating partners can profit quite immediately from progress made in specific fields (productivity, tooling adaptation...)by their colleagues. This makes possible steeper "learning" curves and saves a part of the costs of experimenting.

One of the difficulties in assessing economical aspects of engineering cooperation is that this "way of work" does not make full sense if considered for a single programme, but only in the frame of a long term policy.

Indeed, "education costs", as well as the costs of "creating" a technique or entering a discipline previously procured from abroad, load the first programmes, and corresponding benefits appear only in the following ones. In a comprehensive assessment of economic balances, it is necessary to give some consideration to these aspects, equivalent to a mix of material (specific investments) and non material (build up of experience, manpower, training, etc.) assets.

VI. Conclusion

Recent history has shown the importance and the interest of internatonal cooperation in aerospace activities. Engineering aspects have always been and will remain in the future, the keys to success. Developing proper and efficient ways to insure outstanding engineering activities in cooperation is an essential task of the men and the organisations devoted to the progress of aeronautics.

Several experiences (Airbus, Ariane...) prove that, despite the increased complexity, international cooperation can be organised to provide better results -in the engineering field- than "single partner" developments.

Leaders and participants of our aerospace community must then actively pursue these forms of activities, for the benefit of all.