

## Rapid Salvage and Repair Strategies for Aircraft Disabled or Damaged in Action

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### ABSTRACT

*Wars and battles can be won or lost through attrition, and so there is a critical need for rapid salvage and repair strategies and technologies for aircraft disabled or damaged in action. This is particularly so in view of the trend to greater concentration of capability in fewer aircraft, the need for expeditionary operations, and the long lead times for the manufacture of new aircraft and components. While many of the concepts and technologies addressed in other papers in this Workshop will help in the rapid repair of aircraft, it is necessary also to consider the specific additional measures needed to succeed in a prolonged combat scenario.*

*This paper will address the Session Goal in this context. The scope of the paper is broad. It includes strategies and technologies for retrieving and/or transporting aircraft to repair centres in theatre. It includes maintenance/support concepts and technologies that will allow major component replacements and repairs to be performed quickly in theatre, at forward bases if possible. It includes the design criteria and concepts needed to enable these maintenance/support concepts - e.g., the modular design concept of the French Rafale fighter which takes benefit of the long-standing requirements of the French operations in African or overseas friendly countries (refer to report AGARD-AR-327 dealing with the needs for Deployability). The way these repair “abilities” (say repairability as well) have been incorporated to the fighter “by design” through an ILS approach based on the lessons learnt from the previous programs (including some specific needs for foreign customers) is explained. It includes testability of the aircraft condition, modularity, expertise for its “usability” and finally, it includes concepts and technologies for rapid “battle damage repairs” to components that cannot be replaced in theatre (structure, equipment, tubing, wiring, etc.). These are defined in Def-Stan 00-49 as “essential repairs, which may be improvised, carried out in a battle environment in order to return damaged or disabled equipment to temporary service” or in the French Instruction DEF 800/EMAA which applies to repair of material which has been damaged in “particular circumstances” (including Repair of Damages in Combat - RDC which means BDR). Both try to bring the hardware to a given temporary serviceability (with reduced safety margin) without impairing a later proper repair.*

*Emphasis is put on the “expertise” side of the problem: What is the acceptable level of safety? How can it be modelled and justified?*

## 1.0 INTRODUCTION: REPAIRABILITY FOR AVAILABILITY – THE BATTLE DAMAGE ASSESSMENT AND REPAIR CONTEXT

The whole content of the NATO RTO AVT-144 Workshop “Enhanced aircraft Availability through Advanced Maintenance concepts and technologies” applies to the subject of this document. Even in war, all proper “peacetime” measures which allow to repair an aircraft to restore its availability will be used. Therefore, the subject is too broad to be completely covered by this document, so we do not try to make an inventory of these measures (it is obvious that, when needed and possible, aircraft might be flown back or transported to a maintenance centre), but we concentrate on specific rapid salvage solutions which can be used in wartime where the mission accomplishment becomes an absolute priority (even on the normal level of safety).

The recent trend in increasing number of war operations by coalitions in deployment has made more critical the need to quickly repair the aircraft which have been damaged, in order to keep them available to maintain the tempo of the operations and take the edge over the opponents : deployment can be far from the mother country and logistic resupply times can be incompatible with the operational constraints (transportation time and/or manufacturing time), creating the need for a fast local repair. Therefore “repairability” of aircraft will become a paramount quality in deployment.

Ref. [1] document defines Battle Damage Repair as “essential repair, which may be improvised, carried out in a battle environment in order to return damaged or disabled equipment to temporary service” and Aircraft Battle Damage Repair as “maintenance action taken in wartime to maximize the availability of damaged mission capable aircraft”. The French definition of Ref. [4] document says nearly the same; all try to bring the aircraft to a given temporary serviceability condition (with reduced safety margin) and allowing, when possible, not to impair a later proper repair. They try to answer the questions of Figure 1, below.

### *I have to repair this aircraft.*

- **4 constraints :**

- **Temporal**      *I have xx hours.*
- **Material**      *I have these means (tools, spares, personnel)*
- **Operational**    *I have to do this mission.*
- **Flight safety**   *I accept the risk to do this flight.*

- **2 questions :**

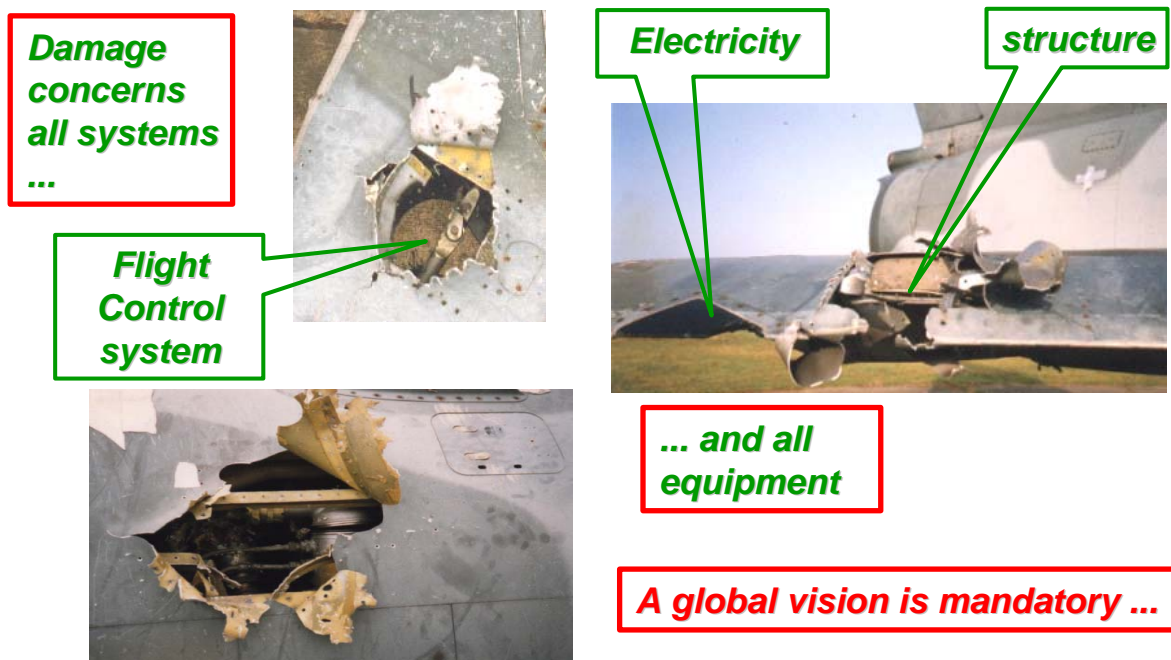
- **Assessment**    *Is it possible ?*
- **Repair**          *How to do it ?*

Figure 1: The Aircraft Battle Damage Assessment and Repair context.

The answer to the assessment and repair questions raise the subject of “repairability”. In our meaning, repairability is a specific part of maintainability, as defined in its broad meaning of the DoD Supportability Guide as: “the ability of a system to be repaired and restored to service when maintenance is conducted by

personnel using specified skill levels and prescribed procedures and resources”. Some public papers have cited the famous B-2 bomber as an example of aircraft difficult to operate in deployment. Its size, range and low observability characteristics allow it to perform very impressive missions, but a 1997 GAO report said it could not be deployed overseas without special climate-controlled shelters; it operates from main bases, and it is why such a base in the Diego Garcia island was equipped with large climatically controlled temporary shelters in order to complement the US basing (see Ref. [6]).

The aptitude to fast “Assessment and Repair” is clearly linked to the aircraft definition and is obviously better on a deployable aircraft. Figure 2 shows, through an example of some combat damages, that the aircraft repair requires a global vision of the different damages (technical assessment, testability of the sub-systems, etc.) and the capability to repair these damages.



**Figure 2: Global vision needed for aircraft repair.**

This aptitude to fast repair exists on the aircraft only if these qualities have been incorporated into the design through an Integrated Logistic Support approach as shown in Figure 3. It is the case for the Rafale fighter which is presented in this document as a good example of deployable and repairable aircraft (but we don't pretend it is the only one).

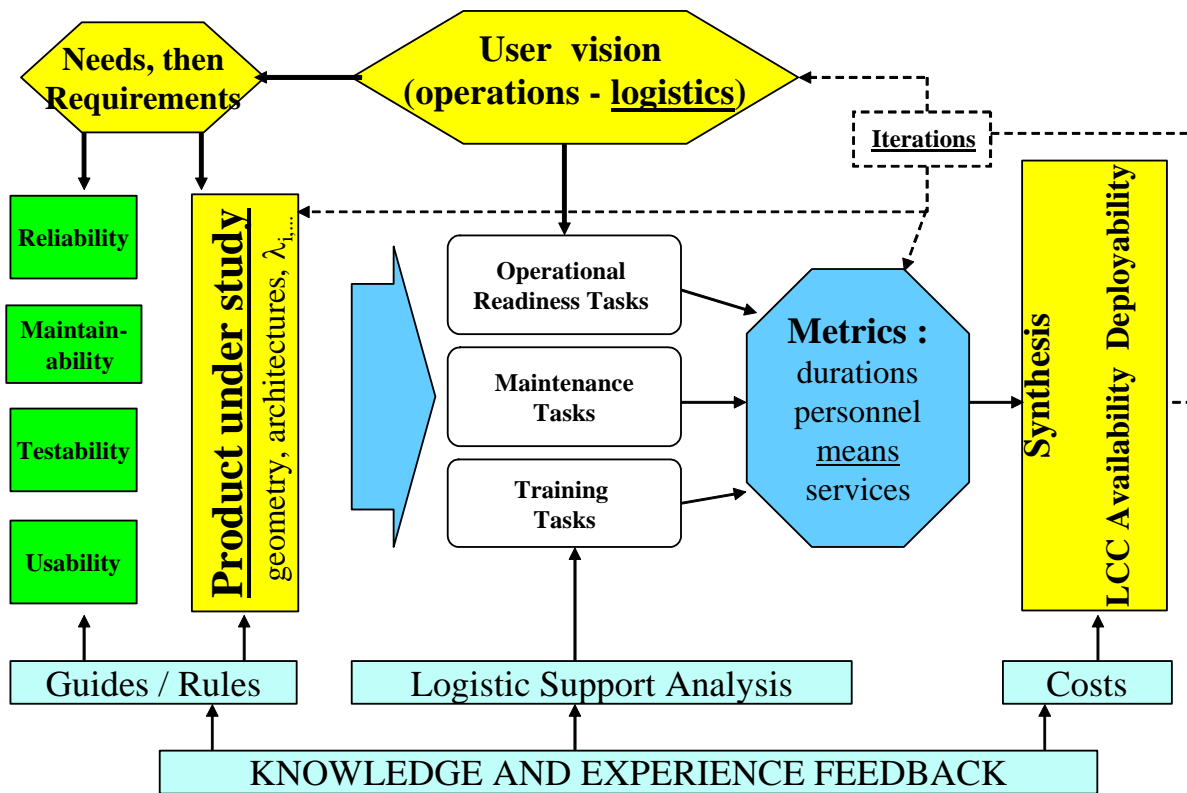


Figure 3: The Integrated Logistic Support approach.

Therefore, this document will explain the French operational background (operational feedback and lessons learnt) which has led to the concept of a deployable aircraft, then will show specific fast repair technologies applicable to the aircraft and finally will discuss the heart of the subject “assessment and safety”: What is the acceptable safety level? (knowing that the acceptable remaining risk level is a political choice between the price given to the objective and the cost of the effort which can be reasonably made), and How can it be demonstrated? (technical aspect of the question).

## 2.0 THE FRENCH AIR FORCE/NAVY AND DASSAULT AVIATION OPERATIONAL FEEDBACK: DEPLOYABILITY & REPAIRABILITY

Ref. [3] document, published in August 1994, gives the results of a NATO Working Group thinking on the ways to improve aircraft mobility and deployability by reducing their dependency on specialized infrastructure and support. It recognized that the “French armed forces have been involved overseas almost without pause” and that their “long-standing requirements of operations in Africa had led to a greater emphasis on the mobility and deployability issues”. “Routinely, French forces have operated from isolated and extremely austere airfields lacking adequate runways ...maintenance facilities, and other basic support services”. From this experience, many lessons have been learnt and implemented in the requirements and the design of “compact, robust, and easily deployable support assets and combat aircraft”.

Among the key deployability features, you will find the OBOGS and the APU; French Air Force pilots who operated the Jaguar and the Mirage F1 in Tchad reported they were sometimes obliged to fly at low altitude

with their mask partially disengaged (to keep the radio) because they had no more liquid oxygen on the base. Of course, the installation of an OBOGS was one of the first requirements for Rafale. The APU which provides energetic independence from the mother base and allows comfortable operations in hot countries was an other example of basic choices for the Rafale (contrarily to what is written in Annex E of Ref. [3] document).

The French Navy, for similar reasons and by tradition, has always been very proud of its autonomy and has put robustness and repairability atop of its mandatory requirements. The need to operate for months from a carrier (which is one of the most powerful ways to deploy) is a strong incentive for such a position. Finally, Ref. [2] document also recognizes that “Built-in deployability and supportability” is one of the major trends for France.

As the single supplier of the French fighter A/C, Dassault Aviation has done its best engineering efforts to put into the design all these “abilities”. This knowledge has been reinforced also by the operational feedback from about 40 different foreign countries all over the world which operate or have operated our military aircraft; some of them have raised specific needs like simple repair solutions. Therefore, main system (the aircraft) and support system are designed together, in a true ILS approach (see Figure 3 hereafter and paper Ref. [5]), to provide products easily usable and repairable in deployment. Recent operations in coalition or in training deployments (such as Red Flag or Maple Flag) have demonstrated the successful operation of our aircraft with very limited personnel and very few means (very small logistic footprint) compared to other participants.

The aptitudes of Figure 3, brought together, are one of the keys to rapid salvage of damaged aircraft in deployment:

- Reliability (simplicity, robustness);
- Maintainability (size and replaceability of components, modularity, repairability);
- Testability (self contained diagnostics, very few GSE); and
- Usability which means ease of use / repair / training.

The other key to rapid salvage in deployment is made of repair techniques as shown hereafter; some are generic but others can apply only to adequate design features, and it is why we consider that deployability and repairability have strong links.

### 3.0 THE LESSONS LEARNT ABOUT BATTLE DAMAGE REPAIR

In 1986, Dassault Aviation delivered the documentation to perform the BDR for the Mirage III and for the Mirage F1. This documentation consisted in:

- Black and white figures showing the damage tolerance examples for the structural parts.
- Description of structural repairs and of the restoration of the functional chains (electric cables, mechanical linkages, tubing, etc.).

In 1990, Dassault Aviation delivered the BDR documentation for the Mirage 2000. Basically, it had the same content but the figures illustrating the tolerances to structural damage were coloured and associated to tables giving a much better readability ; the electrical wiring repair chapter was introduced later by the customer (EET-RDC which belongs to the French Air Force). Figure 4 shows an example of the Mirage 2000 BDR documentation. Though well accepted and considered better than the previous BDR booklet, we considered a

few improvements which led us to a new repair vision as explained in the next chapter. These improvements deal with: the documentation (procedures description), the damage tolerance knowledge, and the nature of the repair itself.

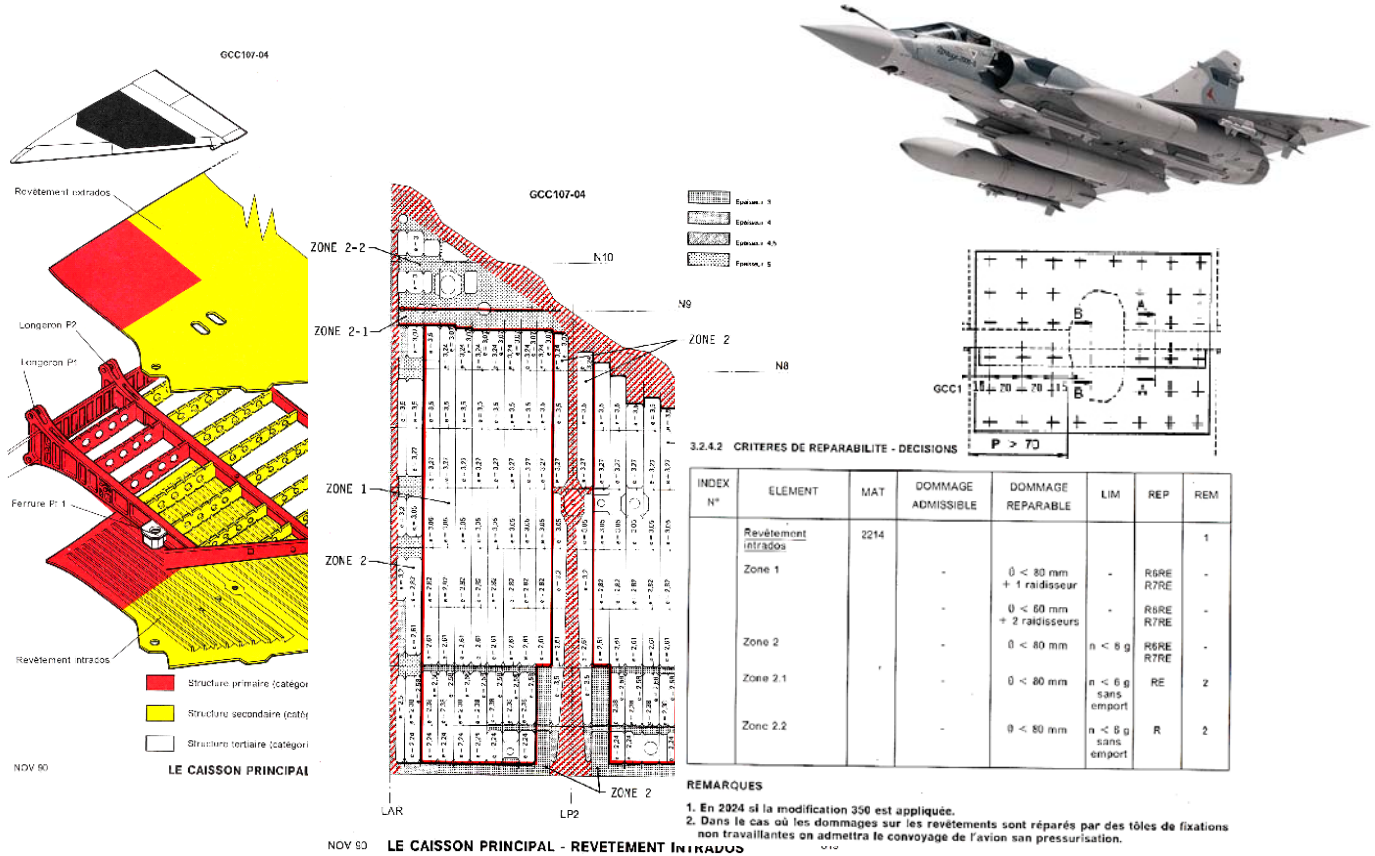


Figure 4: Example of Mirage 2000 BDR booklet content.

- About the documentation, we discovered a representation difficulty for the coherency of the information (concept of “non repairable damage”, link between damage and repair, etc.). We also recognized that the operational impact was not enough discussed (flight envelope limitations) and that the system aspect was not treated (considered, by defect, as being maintained “serviceable” by the user). Finally, we considered that the BDR documentation should be a complement to the normal “peacetime” maintenance documentation and, therefore, that the descriptive parts were not needed (digital documentation now).
- About the damage tolerance, we considered that theoretical studies could be performed using design calculation models and that we should not change the safety margins and we could keep the same structural limit coefficients as for peacetime design.
- About the repair itself, we recognized that, in several cases, the repair was not reversible (peacetime proper “normal” repair performed later) and we considered that existing repair principles could be kept provided a proper optimisation and a qualification by tests. Finally, we envisaged simple rules allowing to apply “typical repairs” to any real case (concept of “repair features” in CATIA as we have “design features”).

## 4.0 THE RAFALE REPAIR VISION

### 4.1 Short Description of Rafale (Used as a Reference for the BDAR Principles)

As said before, an aircraft can be repaired easily only if it has been designed as a repairable item (size and number of the parts (even if it is a trade-off with manufacturing cost), interchangeability, modularity, etc.). Therefore, the repair vision presented hereafter really fits the Rafale, but most techniques or solutions could be used to other aircraft using similar technologies as well. In order to better understand them, we remind the basic design principles of the Rafale, as shown below:

- Structure using composites for 75% of the wet surface and 25% of the weight, new self-reinforced structural elements (co cured ribs inside the composites, titanium SPF-DB elements) and new low observability features.
- Twin-engine A/C with increased redundancies, strong integration of all sub-systems, full integrated testability (structure, aircraft sub-systems, WDNS) with centralized failure management (including visual and voice warnings), new wirings (buses and hyper frequencies), high pressure hydraulics (5,000 psi).

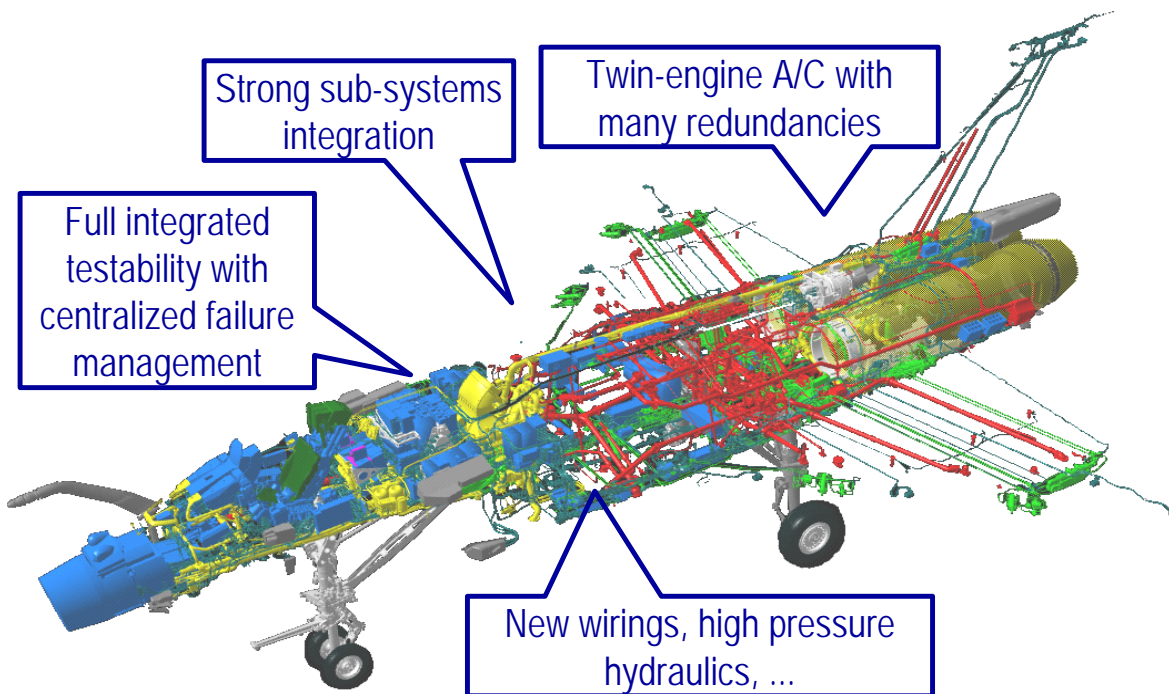


Figure 5: Rafale basic sub-systems definition and integration.

### 4.2 Principles of the Structure Maintenance Study

The BDAR for the structure remains in line and follows the principles of the initial maintenance study of the structure, but with specific requirements. Its principles are reminded below. There is a clear separation between the maximum allowable damages and the maximum repairable damages.

- For the first ones, visual checks or NDI tests are defined with a detection threshold compatible with the safe use without repair.
- For the latter ones, the functional role (structural, electrical continuity, aerodynamics, Radar Cross Section (RCS), etc.) is analysed and the repair is defined to satisfy both the structural strength and the functional performance.
- For both types, the design criteria are simplicity, ease of use and minimum need of Ground Support Equipment (GSE).

### 4.3 The BDAR Concept Evolution

Though the abbreviation RDC (translated Battle Damage Repair) is still in the title of Ref. [4] directive, its application is not limited to war time but includes particular circumstances where repairs have to be performed under constraints of time or of lack of means and where standard maintenance procedures cannot be applied. This has three consequences:

- A degraded level of safety must be accepted;
- The operational capabilities of the A/C must be known precisely; and
- The behaviour in time and the reversibility of the repair must be insured.

During the years 2001 and 2002, a Working Group including Dassault Aviation, representatives of the Ministry of Defence and of the French Air Force and Navy (basically an Integrated Product Team, IPT) conducted studies the purpose of which was:

- To translate the “particular circumstances” concept into Rafale needs;
- To define a methodology to assist the “assessment” or “expertise aspect” (see Figure 6 below); and
- To validate the methodology on a number of examples.

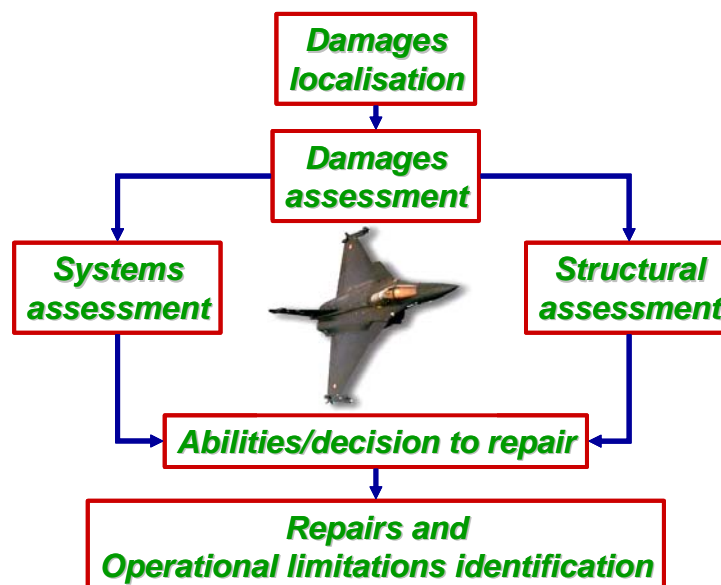


Figure 6: French BDAR methodology as applied to Rafale.



## 4.4 Damage Assessment of the Aircraft

### 4.4.1 Structural Assessment of the Airframe

The first task is to detect the damages by visual inspection or with the use of available NDI standard means. The second task is then to identify the structural elements which are concerned. The third task is to analyse whether the damage is in the allowable limits for “no repair” (allowable damage) or whether it is repairable (dimensions of the damage within the repairable limits). The fourth task is to identify the impact of the potential repair on the structural strength and on other aircraft functional performances in order to define the operational limitations which would apply to the repaired aircraft.

Some significant structural items are not repairable in a BDR context. It is the case for the main structural components, as a general rule, for all integrally machined parts and for some secondary structure components which are subjected to particularly high stress levels (see Figure 7 below for criticality). For those elements, in case of damage, two options exist depending on the “damage tolerance tables” (or, better, on calculation results of the structural strength) and of the mission potential which can be released:

- A certain level of damage will be accepted to perform specific missions (for example Air/Ground mission without external tank under the fuselage).
- A certain level of damage may be permissible by load factor limitation for instance for a ferry flight.

• *Primary structure :*  
*Failure jeopardises the safety or operational use of the aircraft.*

• *Secondary structure :*  
*With a sufficient safety coefficient to allow a significant reduction of its strength before failure.*

- *Tertiary structure :*  
*When damaged might impose flight limitations, but do not in any way affect the safety or operational use of the aircraft.*

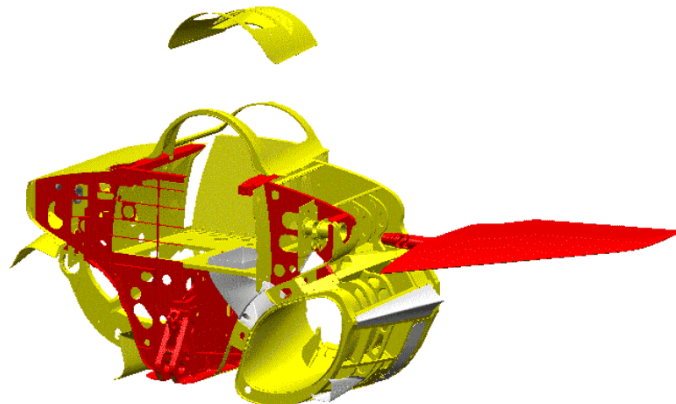


Figure 7: Criticality of structural members.

### 4.4.2 Systems Assessment

With complex modern weapon systems, this task is the most complex task and could justify a full presentation of its own but a major part of the discussion has normally been covered by other presentations of this AVT-144 workshop (like diagnostics and prognostics) ; therefore we summarize only the principles used.



As an extreme example, if the hydraulic reservoir of Circuit 1 is lost, several nominal functions are lost because it is the circuit which performs the auxiliary functions, but the aircraft can still fly with the following limitations : some loss in manoeuvrability, no retraction of the landing gear (only emergency descent), no possibility of “two points only” braking (emergency braking is still there due to park brake), loss of front wheel steering but driveability achieved through differential braking.

Of course, structural and systems assessment must have homogeneous goals and flight performance limitations to decide to put the A/C back to a flight worthy condition.

### 4.4.3 Operational Assessment and Limitations

The logic presented in 4.4.1 and 4.4.2 gives the answer to the operational commander for one specific aircraft. But, in a prolonged deployment or in surge operations, the situation of multiple damages to several aircraft may occur and make necessary the selection of which A/C have to be repaired. Though the answer to this question might be given better with the assistance of modelling tools envisaged for the future (see § 5), the question itself has to be placed here because, even if it is debated today by the officers in charge of the operations and those in charge of the maintenance, the answer will be the repair decision. It will be based on the operational mission value of the repair and on the minimum maintenance and repair tasks which can be performed (personnel and means) to satisfy the need in time (including “cannibalisation” of another damaged aircraft). Depending on the nature of the repair, the remaining safety level might be reduced even with flight envelope limitations. This short discussion shows the difficulty of the overall system and operational assessment, what we called the “expertise side” of the problem in the abstract, and which justifies future efforts to allow a true “full assets management” (see § 5).

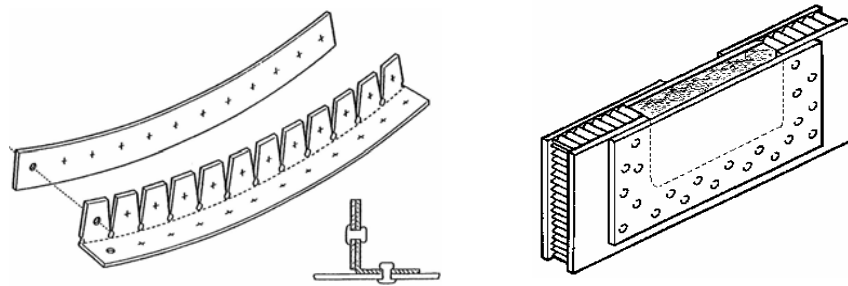
## 4.5 Repair of the Damaged Aircraft

### 4.5.1 Example of Structural Repairs

Their goals are three-fold:

- To reinforce a damaged structure to allow at least 50 more flights;
- To perform the sealing of all volumes containing gases or liquids; and
- To restore the operational functions if necessary (like low observability which cannot be presented here).

All materials used in the aircraft are covered (metallic, composites, honeycomb, canopy glass, etc.) and common means or tools are used. Most Battle Damage Repairs are derived from the standard peace-time repairs. Some others are specific but are designed to allow their rectification during peace-time to fully restore the structural characteristics. A “Combat Damage repair” lot is defined to complement the standard tools and ingredients. Figure 9 below gives a few structural repair examples.



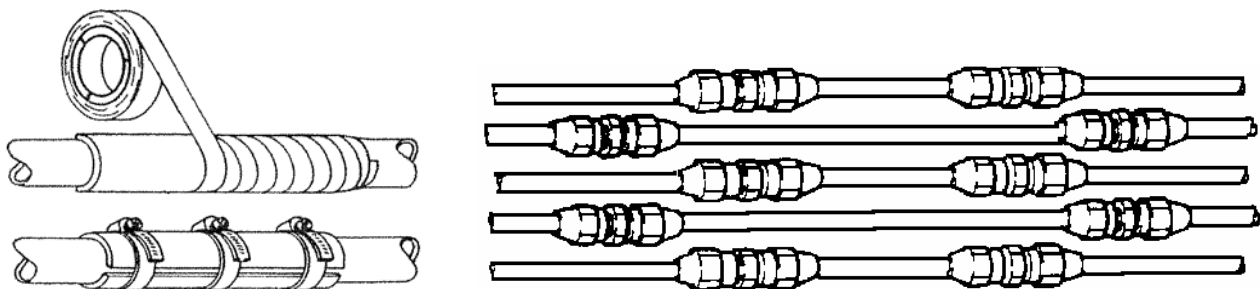
**Figure 9: Basic structural repair examples.**

#### **4.5.2 Engine Repairs**

The M-88 modular design allows the replacement of any LRU and engine module and the return to flight condition without complete bench tests (even if the Charles de Gaulle aircraft carrier has an engine test bench). This basic reparability, applicable in deployment, should cover most damage cases, but other specific repairs are envisaged by the engine manufacturer. They will not be presented here.

#### **4.5.3 Examples of System Repairs**

As a general rule, equipment is not considered as repairable. It is replaced by a spare (including cannibalisation of another damaged A/C) or by a shunt. In fact, some minor repairs may be feasible. The purpose of the repair is to restore the nominal or sometimes degraded function of the considered system (the question being the acceptability of the degraded mode - see system assessment above). Pipes can be repaired with Permaswage or ArsAéro/SM fittings and wirings can be repaired (except UHF cables). Figure 10 below shows examples of pipes repairs.



**Figure 10: Example of basic pipe repairs.**

### **4.6 Strong Points of Rafale Maintenance and Documentation**

To perform his assessment and repair tasks, the maintainer receives a strong assistance, which did not exist for older generation aircraft, from the digital documentation, the integrated testability and new technologies:

- The digital documentation allows to have a maximum information in a minimum volume. In deployment, the whole Organizational and Intermediate Levels (O/L & I/L) documentation is available and we have developed and tested encrypted Tele Maintenance (used during the first

campaign of Charles de Gaulle aircraft carrier). Many improvements remain possible for the future, using numerical models (see § 5) and more generally the new technologies of information and communication (NTIC).

- The on-board Integrated Testability is clearly one of the key tools to assist the maintainer for the systems assessment, as explained before. It can be completed by already existing tools like the Interactive Trouble-shooter Assistant System (ITAS) which uses the “failure words” of the Integrated Testability to guide the diagnostic task of the maintainer.
- New technologies facilitate the repair itself. It is the case for the wiring identification by bar-codes and portable readers, and for titanium tubing and Permaswage junctions which can be cold-crimped for hydraulic circuits. Both are represented on the Figure 11 below.



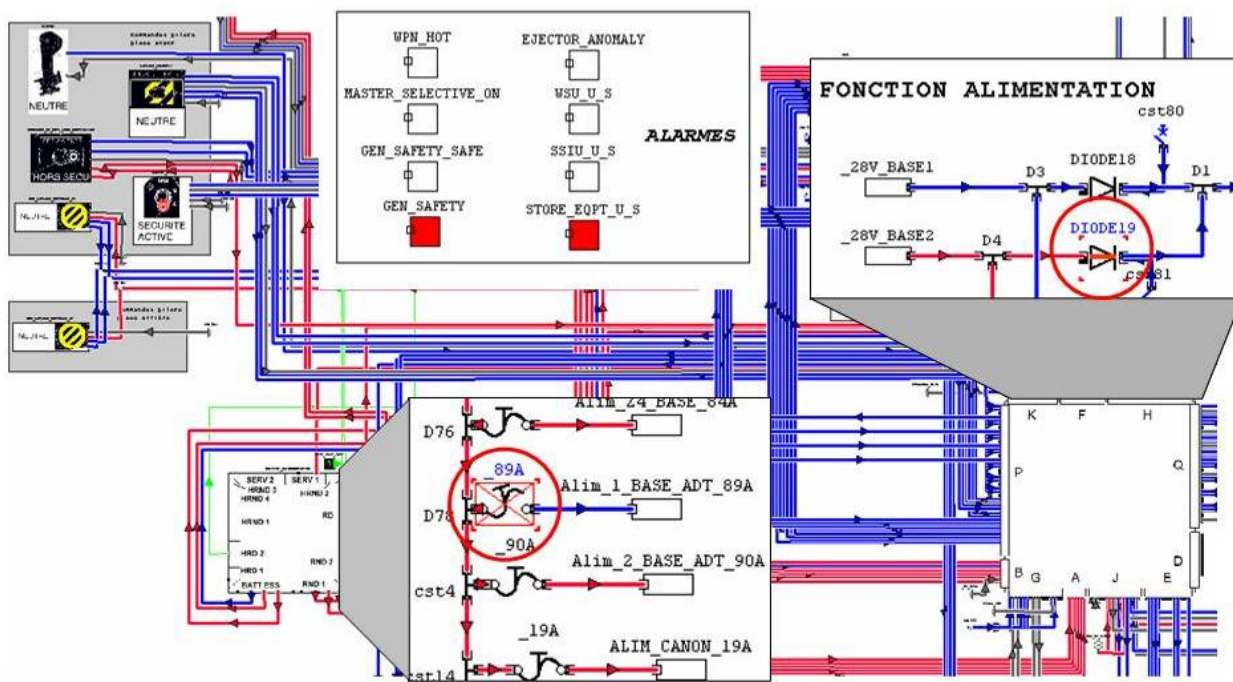
Figure 11: Examples of technologies making identification and repair easier.

### 5.0 FUTURE FORESEEN IMPROVEMENTS: ASSISTANCE TO THE A/C ASSESSMENT AND REPAIR DECISION

As seen before, the overall A/C assessment and the decision to repair or not is the central problem of the BDAR context ; it is the most difficult question to answer, and specially in a prolonged deployment situation where multiple damages can occur while the critical need to perform missions persists, awaiting for resupply of spares. New tools can assist the operational and maintenance officers to take their decision ; the first one can assist the overall system assessment of each damaged A/C, the second one can assist to take the repair decision between several damaged A/C. Though already tested, they are not yet integrated in an operational usable decision making tool, but for the interest of the Workshop subject, they are presented hereafter.

As part of our engineering design process and for aircraft certification, we use a “dependability” suite of tools, initially developed in-house with research institutes but commercially available since years under the name CECILIA. Its failure trees have been used for many years, but we now use new functionalities developed for our flight controls. One of them is the dysfunctional model of sub-systems : each equipment can be represented with different operable or dysfunctional states (failure or damage). Once all sub-systems have been described with such a tool, it becomes possible to visualize the combined effect of several failures (or

damages); this is equivalent to an FMECA analysis as it gathers all the information leading to a “warning” condition or to a red “NO GO” condition. Connected to the failure trees, it can give also the resulting probability of occurrence of a number of “feared events” and give the decision maker the indication of the “remaining safety”. This is for the “technical assessment” of the systems on one specific A/C. The Figure 12 below shows an example of a rather simple page of the tool.



**Figure 12: Use of CECILIA Workshop to assess a combined damage (or failure) criticality.**

Bayesian Networks can be used as decision assistance tools. We used such a tool for repair decision making in a BDAR context (simple prototype tool but which gave the expected results on simple cases). The principle is the following. The operations officer selects an aircraft tail number and a mission to perform : a list of repairs and of their foreseen durations is associated to the aircraft tail number (automatic extraction from the on-board integrated testability completed, if necessary, by further complementary investigation as seen before) and a Minimum Equipment List is associated to the mission. A Bayesian network of the functional equipment needed for the mission is built and the tool evaluates the different combinations of repair options (represented by different shapes and colours on Figure 13 below). The calculation report gives a graph indicating the mission success probability as a function of the potential repair duration. The example represented below shows that the repair of one specific critical equipment can give a major increase in mission success probability. Similar graphs would be generated for each envisaged tail number, allowing the operations officer to select the best A/C for the priority mission. This simple example shows the interest of decision assistance tools when the number of damages increases.

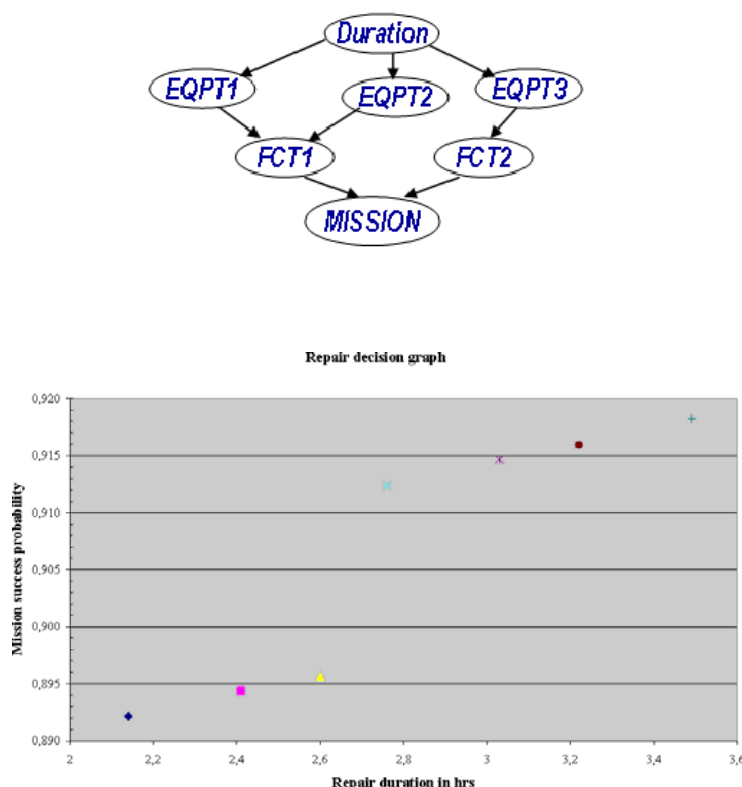


Figure 13: Bayesian network used as a repair decision assistance tool.

Finally, INDET European research program, to which we participated, tries to associate 2D structural representation to NDI results and, associated with finite elements structural strength computer models, to allow a very rapid assessment of a structural damage in composites. 3D extensions are presently in development. This kind of tool could be very useful to assist the structural repair decision.

The above examples show a few potential tools developed and proven by the engineers but some essential questions have to be answered : Will these tools be available and usable by the operational people in deployment ? As they contain the very knowledge of the designer, how are the intellectual property rights satisfied contractually ? There are probably different answers to these questions depending on the customer : some will like full decision autonomy, having their own experts ; others may prefer simplified decision tables (as it is the case in present BDAR brochures) or simplified executable models or even use Tele Maintenance assistance from the A/C manufacturer.

## 6.0 CONCLUSION

The subject of this AVT-144 Workshop theme was very broad and ambitious and we are conscious that all “faces” of the subject could not be treated in a single paper. Before the workshop takes place, it is also difficult to know to what depth other topics (like Diagnostics / Prognostics) which contribute to the subject will have been treated. Therefore this paper necessarily duplicates some information existing in other presentations and, on the contrary, cannot discuss other majors aspects (like retrieval, transportation, etc.) ; it concentrates on the reparability and on the damaged aircraft functional assessment.

Though we were not the initial authors of the abstract, we accepted to take the lead for this document because Rafale had been cited in the original abstract as a good example of deployable and repairable aircraft, and we considered it was our role to show it. But the subjects we have raised are universal and apply to many aircraft facing the same context of Battle Damage Assessment and Repair. Through the example we used, it looks clear that the major challenge in a BDAR context is the “system assessment” (expertise) and that it will be the case for any new modern weapon system. It is obvious that integrated testability is a powerful tool to assist the subsystems assessment and that modularity and structural repairability (size and removability of parts) are strong enablers to put the A/C back to a flight worthy condition. Both are available if they have been incorporated to the design through an ILS approach; it is what we have tried to do on Rafale to make it a deployable and easily repairable A/C.

NTIC and computer models can still offer a significant improvement potential to assist the repair decision. We are clearly in favour of interactive computer tools which bring a considerable improvement over static charts or data bases or manuals which cannot fit as closely the real damage to assess. It would be a subject by itself to review them in detail due to their fast progress ... and it is also probable that several of them will have been presented in other sessions of this workshop. As a simple example of further improvements, we have demonstrated solutions to keep on the hardware (A/C part or equipment) the description or the indication of the repair which has been performed (4 Kbytes RFID tags or memory buttons - both have been tested successfully to the aircraft environment) and, thus, to facilitate further proper repair in peace-time with simple update of the repair information which is also automatically transferred to the Maintenance Management System. The major advantage is that the “source information” is on the hardware itself where the work has been performed and that it avoids the very well known loss of accompanying documents.

## **7.0 REFERENCES**

- [1] List of Definitions for AVT-144 (advisory).
- [2] Context notes for the NATO RTO AVT-144 Workshop.
- [3] AGARD-AR-327 Options and implications for increasing mobility by reducing dependency of NATO combat aircraft on specialized infrastructure and support.
- [4] DEF 800/EMAA Instruction relative au concept de réparation des matériels endommagés lors de circonstances particulières (RDC) = Instruction for repair concept of material which has been damaged in particular circumstances.
- [5] RTO-MP-37 - Paper 6 : Supportability in Design and low Life cycle Cost : the Mirage 2000 example.
- [6] Set of public papers on the Northrop Grumman B-2 bomber: Jane’s Defence Weekly 27/08/1997 – International Herald Tribune June 2001 – Flight International 5/11/2002, 31/12/2002 and 27/04/2004.