Conservation of a WWII Supermarine Spitfire section wing

Conservação de uma secção de asa de um avião *Supermarine Spitfire* da II Guerra Mundial

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Abstract

This study focuses on a WWII Supermarine Spitfire aircraft section wing conservation, salvaged from the seabed in 1988 and stored in a private garden. The object was in poor condition so decisions on the conservation, preservation or removal of parts of the original elements were needed. Firstly, the wing fragment was studied to determine its heritage interest and to assess its historical, industrial, technical and scientific values. This object will become a memorial to the pilot who died during the mission, in his hometown. The conservation project aims to find the best solution to both conservation priorities and exhibition needs. Based on cleaning tests on corroded, painted aluminium alloys carried out within the PROCRAFT Project, a treatment was determined. This case serves as an example of how the results of a European project can be implemented in a conservation-restoration process and how industrial conservation theory can be applied to archaeological artefacts.

KEYWORDS
WWII cultural heritage
Aluminium alloys
Supermarine Spitfire
Cleaning treatment
Conservation-restoration
Archaeological artefact

Resumo

Este estudo considera a conservação de uma secção de asa de um caça *Supermarine Spitfire* da Segunda Guerra Mundial, resgatada do fundo do mar em 1988 e armazenada num jardim privado. O objeto encontrava-se em mau estado de conservação, sendo necessário decidir sobre a preservação de partes dos elementos originais. A asa foi estudada para determinar o interesse patrimonial e avaliar os seus valores histórico, industrial, técnico e científico. O objeto tornar-se-á um memorial ao piloto que morreu durante a missão na sua cidade natal. O projeto de conservação visa encontrar a melhor solução para as prioridades de conservação e as necessidades de exposição. Com base em testes de limpeza de ligas de alumínio pintadas e corroídas, realizados no âmbito do projeto PROCRAFT, determinou-se um tratamento. Este caso ilustra a aplicação de um projeto europeu num processo de conservação e como a teoria da conservação industrial pode ser aplicada a artefactos arqueológicos.

PALAVRAS-CHAVE
II Guerra Mundial
Ligas de alumínio
Supermarine Spitfire
Limpeza
Conservação e restauro
Artefacto arqueológico

Introduction – the PROCRAFT project

The Second World War (WWII) is often considered to be the golden age of military aviation, with aircraft symbolizing modernity and power. They played an important role in legendary battles, such as the Battle of Britain and D-Day, which involved around 14,000 planes (fighters, bombers and transport aircraft). During this period, the USA built over 250,000 aircraft, while the other countries produced no fewer than 500,000 planes. Most of these aircraft were either lost in combat or disappeared during war missions. Many remains can be found across Europe, both on land and at sea. At the end of WWII, some of the remaining aircraft were used in other conflicts, but the majority of the machines were scrapped, melted down, or left to corrode. Thus, for example, out of the 12,731 specimens of "B17 Flying Fortress" only 20 have survived to the present day. This represents 0.15 % of one of the most widespread models, while other types of aircraft were practically all destroyed [1]. In France, not a single example of the two most produced French WWII aircraft, the Morane-Saulnier 406 and the Potez 63, has been preserved [2].

WWII aircraft heritage has an undeniable historical and emotional value for Europeans, but these archaelogicals remains have only recently officially entered the field of archaeology and cultural heritage conservation. Their presence in national museums is limited. They are often cared for by volunteers and volunteer-led associations.

The discovery of an airplane wreck is challenging from several points of view: its composition and materials, its history, its legal statutes and its size and condition.

To meet these challenges, Arc'Antique laboratory has collaborated since 2020 with four main partners: CEMES – Center for Material Elaboration and Structural Studies, University of Bologna, University of Ferrara and Czech Technical University in Prague, and 21 associated partners in the PROCRAFT project (PROtection and Conservation-Restauration of Heritage aircrAFT). The last ones include scientists, State representatives, conservators, academics, museums, associations, from Canada, Greece, Sweden, Italy, Czech Republic and France. They represent all the various actors in this heritage chain benefiting from their joint expertise and capabilities.

The goal of the PROCRAFT is to create innovative procedures and solutions for each key step in aircraft conservation:

- Tailored conservation-restoration techniques;
- Smart coatings for outdoor protection respecting the requirements for safeguarding cultural heritage;
- Innovative solutions for preventive conservation in confined or semi-confined environments;
- Guidelines for aluminium (Al) alloys conservation for volunteer groups.

The results of this project will:

- Enhance and share knowledge about the conservation of WWII aircraft, focusing particularly on the conservation of Al alloy components;
- Contribute to the preservation of aircraft heritage;
- Promote dissemination and presentation of our work to the public.

Project phases (WorkPackage –WP) (Figure 1) within the PROCRAFT aim to:

- Document constituent materials and related alterations to aircraft wrecks from six nations involved in WWII (WP 2).
- Carry out chemical and mechanical cleaning tests depending on the corrosion layer and composition (WP 3).
- Deliver surface protection studies for Al alloys (WP 4).
- Understand the sensitivity of alloys according to their composition and state of degradation, characterize galvanic corrosion and active corrosion processes to implement suitable treatment (WP5).

- Define guidelines for preventive conservation of aircraft wrecks (WP 6).
- Ensure public awareness and dissemination of information gained from the project (WP 7).

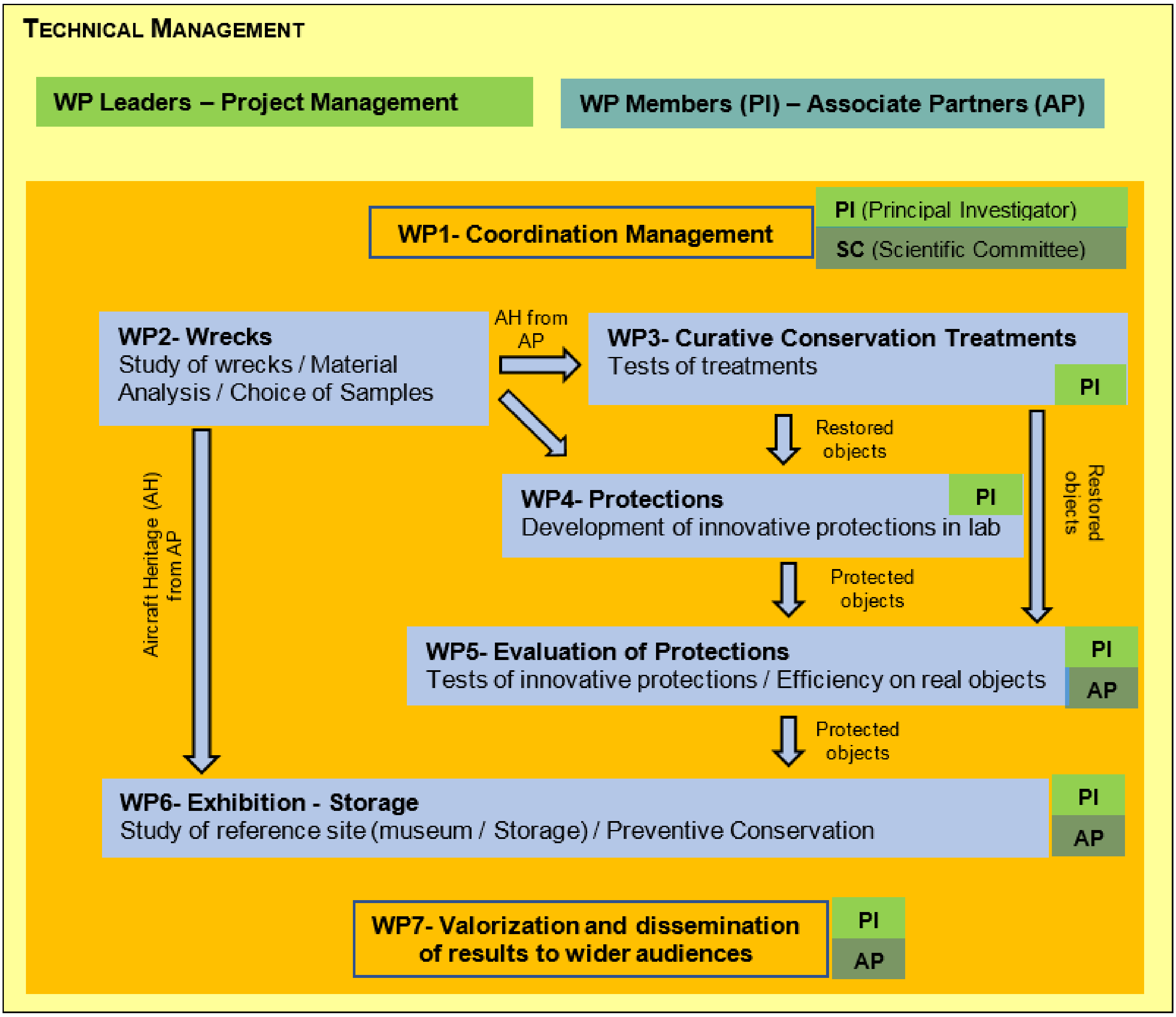


Figure 1. Organization of project phases within PROCRAFT.

Within the framework of the PROCRAFT, one of our associate partners, the Department of Underwater Archaeological Research in France (DRASSM), entrusted us with a wing fragment from a Spitfire Mk VII MB887 to carry out tests for WP purposes. The Spitfire wing fragment encompasses the whole range of challenges involved in conservation and long-term preservation of aircraft heritage wrecks: 1) large surface with remnants of original paint, 2) varying states of degradation and corrosion aspects, 3) inaccessible parts, 4) no climate-controlled storage environment.

Due to its historical and technical value, we decided to use the results of WPs 3 and 5 to manage a global conservation project centred on the Spitfire fragment. This paper focuses on the direct application of the first PROCRAFT results for the conservation-restoration of this WWII Supermarine Spitfire aircraft wing fragment. The broad outlines of WP 3 results are presented but details outcomes are not shared.

Firstly, this study set out to assess the aircraft's heritage value and to adapt our archaeological conservation-restoration processes accordingly. After a complete diagnostic, parts that could be saved were selected. Stabilization treatments were assessed, and cleaning tests were performed to determine suitable treatment conditions for a damaged, painted Al alloy. This paper presents the different actions carried out to ensure the conservation of the Spitfire wing as an example of collaboration and joint decision-making process between various stakeholders including volunteers, conservators, and state representatives.

Supermarine Spitfire aircraft: Historical and technical studies

The WWII Supermarine Spitfire aircraft wing was salvaged in 1988 from the seabed less than three miles off the French coast in the English Channel. The fragment represents the leading edge, the front part of a "universal type" (or Type C) starboard wing. The machine guns are missing but some landing gear parts were still attached. The object was saved from destruction by a volunteer who kept it for over 30 years in his garden. Local authorities, supported by the "Association Bretonne du Souvenir Aérien 39-45" (ABSA 39-45 association) and the DRASSM, responsible for the object's conservation, decided to restore the wing fragment and exhibit it as a memorial in honour of the pilot who gave his life to liberate France.

The Spitfire is an iconic WWII fighter aircraft which played a pivotal role in the war in the United Kingdom air defense. It was also used as a fighter-bomber to attack targets in Europe, as well as in North Africa, the Mediterranean and the Middle East. On 1st June 1944, during Operation Rhubarb to neutralize a cargo train in France, Officer James Atkinson, a 22 year-old Australian pilot, was reported missing at sea with his plane, the MB887. Forty-four years later, off the coast of Saint Brieuc, a French fisherman recovered the wing fragment, which was authenticated by its identification plate.

The Spitfire was continuously produced in large quantities throughout WWII and underwent many modifications to improve its performance [3]. The Spitfire Mk VII was developed specifically for high altitude flying, and only 140 were produced. One of its innovations was the presence of two symmetrical radiators under the wings for the supercharger and oil cooler. This Spitfire model also had an internal fuel tank in the wings for high-altitude climbs. The tank is still present on the recovered wing fragment (Figure 2) and comes from a relatively uncommon Spitfire model. A complete example is exhibited at the Smithsonian's National Air and Space Museum, but this particular plane never took part in active combat, being used only as an evaluation aircraft. The wing fragment has great authentic historical value and symbolizes the memory of the fallen Australian pilot. It is of significant value from several points of view:

- Historical value: representative of an iconic WWII aircraft, the object is a poignant symbol of the deadly air battles of the time.
- Scientific and technical value: the object is one of a series of only 140 and features a major fuel tank innovation.
- Social value and authenticity: the object is directly linked to the death of the young Australian pilot James Atkinson (bullet impact marks are visible on the wing), and could be a fitting memorial to him, highlighted with explanations on the historical context.
- Aesthetic value: despite deterioration due to its long exposure to seawater, the object can be easily interpreted and its function understood.

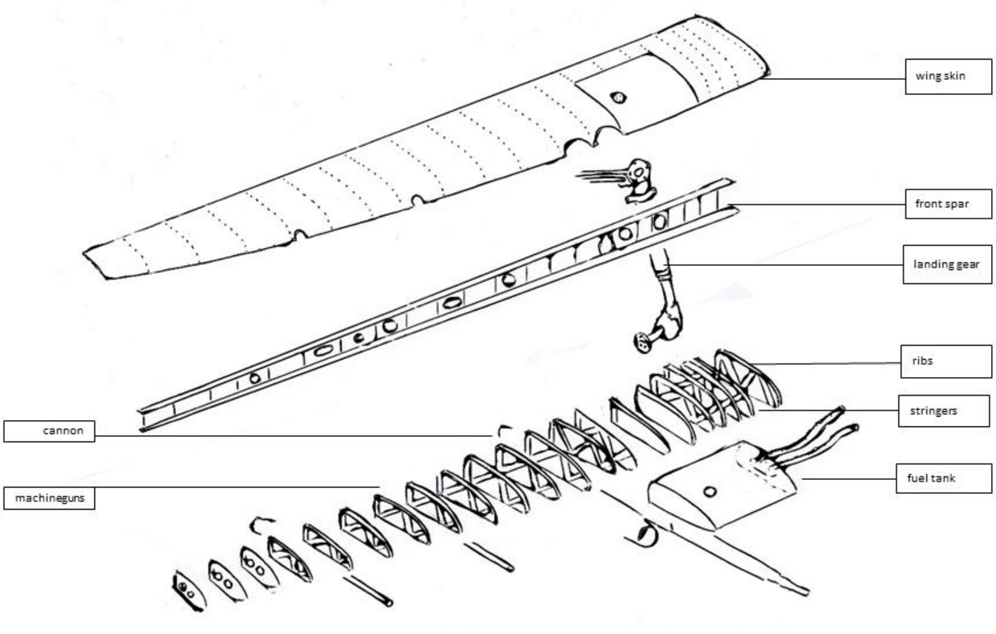


Figure 2. Exploded view of the Spitfire Mk VII wing fragment.

Materials and methods

SEM-EDS analysis

To determine elemental composition, small-sized samples were cut from the object, and were embedded in epoxy resin, polished with 800-000 SiC grade paper and finally polished by cloth with diamond paste from 3 µm down to 1 µm. Scanning electron microscopy (SEM) JEOL JSM 5800LV, operated at 20 kV and coupled with Energy Dispersive X-Ray Spectroscopy (EDS), was used to analyze the elemental composition. EDS acquisition was performed on six areas of 500 × 500 μm^2 with a minimum of 100,000 counts on each spectrum.

Gel preparation

Agar gel

This is a gelatinous agent consisting of polysaccharides that come from a species of red algae. It is compatible for use in solutions with a pH between 5-8. AgarArt (supplied by CTS) was used as 3 wt % AgarArt. The treatment solution was heated to 50 °C before slowly stirring in the Agar Art powder. It was then heated to 90 °C until the mixture became homogeneous and translucent. After cooling for 24 hours, the gel was heated a second time to 90 °C. For spray application, the gel was inserted into a spray gun tank at 70 °C. The gun used was a Wagner W450 wall sprayer model.

Xanthan gum

This is a gelatinous agent consisting of polysaccharides, obtained by the fermentation of simple sugars using bacteria. Both products are basically Xanthan gum but Vanzan (supplied by CTS) is industrially modified. It is compatible for use in solutions with extreme pH. Xanthan Gum (supplied by Kremer) was used as a 2 wt % whilst Vanzan was used as a 5 wt %. The treatment solution was mixed with Xanthan powder at room temperature and the gel was used 24 hours after preparation.

Examination and diagnosis

The object is fabricated from: Al alloys, ferrous alloys, elastomers, synthetic materials, paint (remains).

The wing is mainly fabricated from Al alloy (Al-Cu) that is highly sensitive to corrosion. SEM-EDS analysis determined that most parts are made of Duralumin with an elemental composition of Al (93.3 %), copper – Cu (4.2 %), magnesium – Mg (0.9 %), manganese – Mn (0.65 %), silicon – Si (0.5 %), iron – Fe (0.4 %) and traces (nickel – Ni, zinc – Zn, titanium – Ti, chromium – Cr). Records [3] show that Duralumin parts were protected by Al cladding (pure Al hot-rolled on both sides of the alloy, to provide more resistance to corrosion) and painting. However, SEM analysis of samples taken from different areas of the wing did reveal cladding only on the stringers. Residues of the original paint are still visible on the upper skin with an average thickness of 20 µm.

After 44 years on the seabed, the wing fragment was stored for a further 34 years in a private garden (Figure 3). The plane's history has resulted in a wide range of visible deterioration; mechanical degradation caused by the combat and crash (Figure 4a), deterioration due to seawater (Figure 4b-c), and the presence of undergrowth during the period of outdoor storage in the garden (Figure 4d). In our conservation process we undertook a full condition assessment including of the mechanical and electro-chemical deterioration. The main observations are summarized in Table 1.

Figure 3. The Spitfire Mk VII wing fragment stored in the garden.

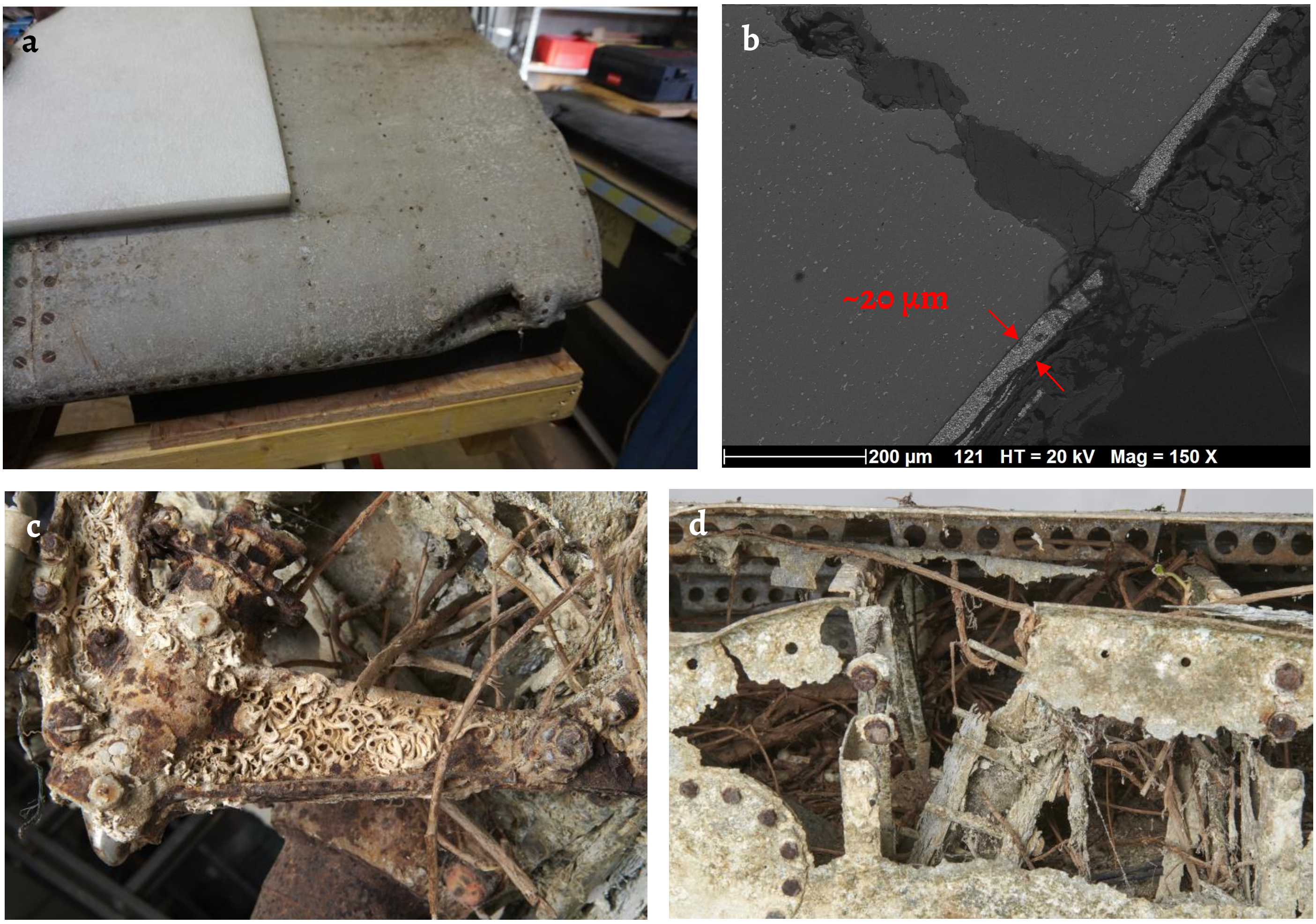
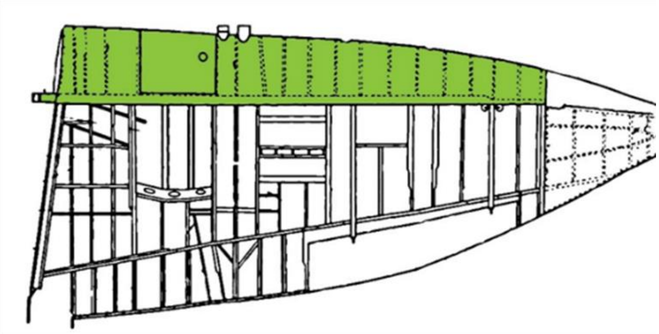
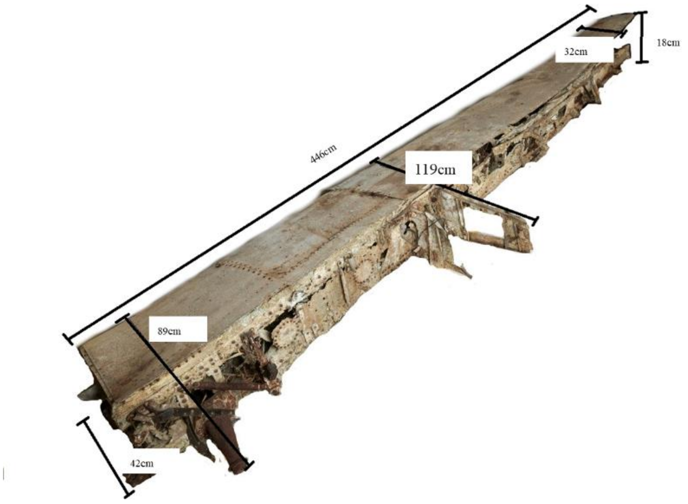
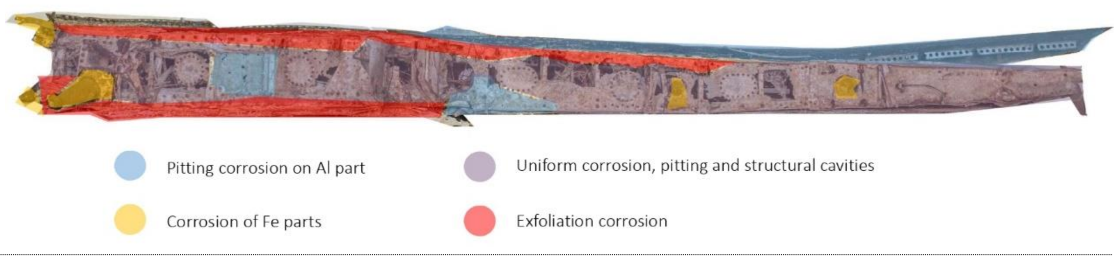


Figure 4. Examples of deterioration observed on the wing fragment of the Spitfire Mk VII: *a)* bullet impact; *b)* SEM photo of a sample (cross-section) from the wing showing generalized corrosion with inter- and intragranular corrosion in relation to micrometric intermetallic precipitates; *c)* development of marine microorganisms, called "concretions"; *d)* presence of undergrowth inside the wing.

The most severe mechanical degradation of the aircraft probably dates from the time of the crash. The fisherman recovered only the front part of the starboard wing which accounts for no more than 30 % of the total area of a Spitfire wing. Significant degradation also took place during the period it was in the sea and stored outdoors. The internal structure had undergone extensive damage. There are major differences of state between the interior and exterior parts. The internal wing structure was in poor condition; the front spar, stringers and ribs no longer provided adequate mechanical strength due to major exfoliation and pitting corrosion. The corrosion had buckled and lifted the Al sheet (Figure 5). The ribs near the tank were in good condition, while others were in very heterogeneous condition (poor to very poor). All of the ribs displayed localized corrosion, some of which had deteriorated into exfoliation. The location of the different degradations, which were classified into four categories: localized corrosion with pitting, original paint residues, rust stains and missing rivets (Figure 6). The skin (top and bottom) was in good condition overall with traces of paint still visible (Figure 3). Paint remains were abraded and poorly preserved. Localized mechanical surface alterations were visible but did not impact overall legibility.

Table 1. Summary of the main damage identified on the Supermarine Spitfire aircraft wing fragment.

Description	Scheme
Fragment location scheme The recovered fragment is colored in green on this diagram which shows a Spitfire wing in its entirety	
Size Recovered dimensions: Length: 446 cm High: 18 to 42 cm Width: 32 to 119 cm	
Main alterations caused by corrosion	 
Main mechanical alterations	- Adherent and non adherent deposits (marine concretions/remains of vegetation) - Severe deformations, gaps, uncoupling, cracks, breaks, missing structural elements mostly (95 %) on the internal structure - Mild deformations, gaps, cracks, stains and missing structural elements on the skin structure (30 %)

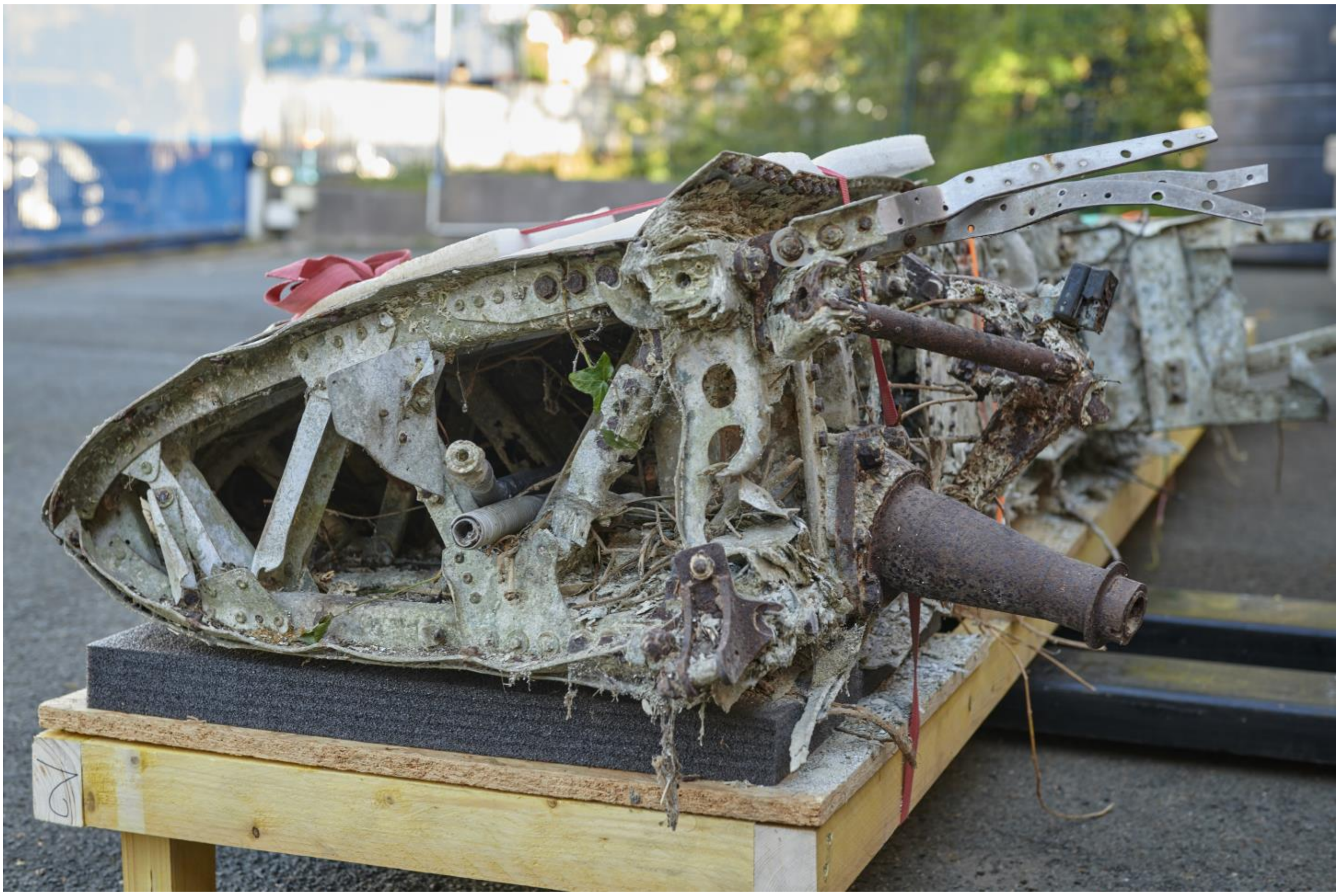


Figure 5. Exfoliation of the spar which caused the Al sheet to buckle.

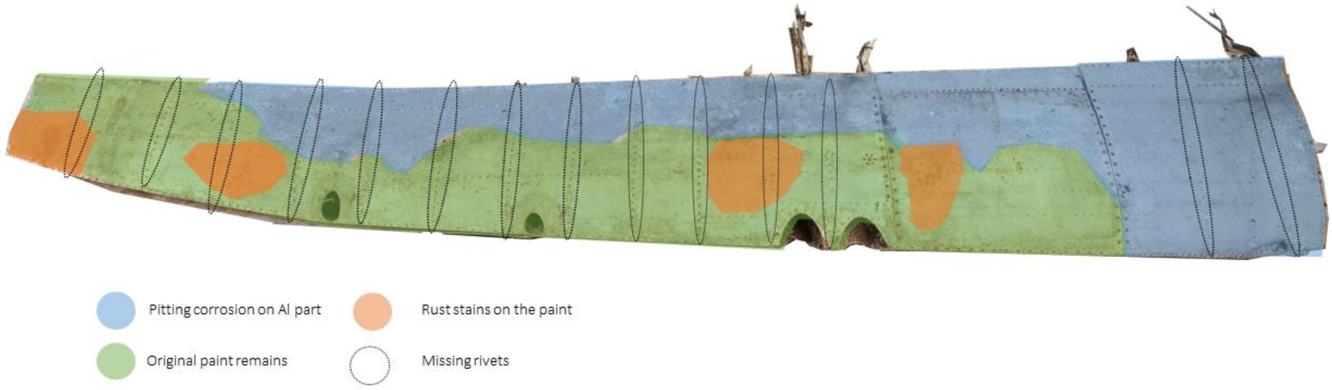


Figure 6. Location of various degradations on the wing fragment of the Spitfire Mk VII.

Mechanical damage due to bullet holes was visible on the side of the location of the machine guns. Most of the rivets that attached the ribs to the wing skin were missing. These Al-Cu alloy rivets are richer in Mg than Duralumin and are more susceptible to corrosion. The tank and elastomer parts do not seem to have deteriorated. The Fe bolts had resisted better and were still present. On the other hand, the presence of Fe elements had caused galvanic corrosion by accelerating the degradation of the Al alloys. The Fe elements were slightly corroded, and Fe corrosion products had caused rust stains on the surface of the wing.

Duralumin is highly sensitive [4] when in contact with chlorides, developing pitting and intergranular corrosion aggravated by the presence of intermetallic precipitates (Figure 4b).

Records [3] show that Duralumin parts of the Spitfire were usually protected by Al cladding (pure Al hot-rolled on both sides of the alloy, to provide more resistance to corrosion) and painting. However, SEM analysis of samples taken from different areas of the wing did not reveal any cladding. During the period of storage in the garden, the wing fragment was under a plastic tarp, surrounded by vegetation which generated humid conditions resulting in increased Al alloy corrosion. Localized corrosion had become generalized in some areas, especially at the level of the internal structure. Al alloys are highly sensitive to variations in relative humidity which produces mechanical stress and enhanced mechanical deterioration. The disappearance of the rivets due to corrosion had worsened the mechanical condition of various elements which were no longer physically held together.

Pitting and intergranular corrosion is common in archaeological Al alloy wrecks. In the case of a DC-3 aircraft wreck [5], variable degradations were observed: some parts were very degraded, while others looked as if they had just come out of the factory. For wrecks salvaged from the sea, the first treatments to be developed were inspired by the stabilization of ferrous materials [6-10] involving chemical or electrochemical rinsing to remove chlorides. However, a study on the effectiveness of these treatments showed that very few chlorides remained present in the Al alloys [11] when the object is no longer in contact with a chloride environment. In fact, the absence of compounds containing chlorine and aluminium is probably due to the high solubility of these compounds [12]. The chloride extraction treatment step is therefore not considered necessary, but additional conservation treatments remain essential to ensure the preservation of this type of Al alloy wreck.

The wing skin was in relatively good condition but required cleaning. Due to corrosion of the Duralumin, internal structure parts were in really poor condition, particularly the front spar and stringers (Figure 2). The front spar is the major structural element and this required urgent remedial conservation treatment (Figure 4d) as it had developed extensive exfoliation. Stringers needed consolidation, while some ribs that were too severely degraded had to be removed (about 10 %).

Conservation objectives

By taking into account the object's history and background, conservation state, diagnosis results and exhibition expectations, we determined the following conservation objectives:

- All elements that improve the overall understanding of the functional and technical characteristics must be preserved and consolidated, whereas corrosion products or parts that are not relevant to the object's original function should be removed.
- Because of its archaeological origin and the fact that remnants of paint subsist in some areas, the final surface appearance will be homogenized rather than standardized.
- Non-adherent exogenous deposits will be removed as well as marine concretions. Surface corrosion products, mostly hydrated aluminium oxide, will be cleaned or removed.
- An exhibition will take place in the town hall close to where the wreck was found. It is an indoor environment with unstable environmental conditions. Sufficient surface protection will be provided to ensure the stability of the metal and compounds.

Treatment has been carried out for a three-month period using the results of tests from the WP 3. The most suitable treatment for the Spitfire wing has been chosen to achieve conservation objectives.

PROCRAFT: results of previous cleaning tests

As the wing surface presented varying surface conditions, the specific treatment protocol had to be determined, and therefore the results of previous testing were considered. WP 3 research established cleaning protocols by carrying out tests on metal surfaces, corroded surfaces and painted surfaces from authentic WWII aircraft wrecks. The objects included a propeller blade from an unidentified aircraft found in the Bay of Brest, a stiffener fragment from a Dewoitine D338, abandoned after WWII near Marignane airport (France), and a plate fragment from a Messerschmitt Bf109, which crashed during WWII at Le Rheu (west of Rennes, France). Assessment and description of corrosion layers were carried out on the different objects before evaluating different cleaning methods.

In these cleaning tests, mechanical techniques and chemical treatments were compared. The mechanical techniques, most widely used by conservators, such as brushing with or without water, using a scalpel, micromotor and blasting were tested. Results are shown in Table 2.

Chemical treatments were applied using Agar or Xanthan gels. Many of the treatment solutions were selected based on previous studies on Al alloy treatments. All chemical treatment solutions are listed in Table 3. On this type of surface, rinsing only took place when all the other treatments had been carried out, and consisted of very light rubbing with a cotton swab soaked in deionised water, until no further residue was deposited on the swabs.

Table 2. Mechanical techniques used and the results obtained.

Mechanical Treatment	Impacts on clean metal surface	Impacts on corroded surface	Impacts on painted surface
Scalpel	- Unsuitable - Time-consuming for large surfaces - Risk of scratching	Suitable for local corrosion products	Suitable for local use
Micromotor with steel brush	- Unsuitable - Time-consuming for large surfaces - Risk of scratching	Unsuitable	Unsuitable
Blasting with a vegetal abrasive		Most effective in removing mild surface corrosion, resulted in a homogeneous surface.	
Soft brush with deionized water			Only effective if the paint adheres strongly to the surface

Table 3. Chemical treatments used and the results obtained.

Treatment Solution	pH	Gel	References	Results
Citric acid (0.055 M)	5.4	Agar	[13-14]	citric acid or tri ammonium citrate (TAC) solutions remove corrosion products, but it took at least 6 to 12 ten-minute applications of gel to achieve a clean surface with a shiny finish
Tri-Ammonium Citrate (TAC) (5 % w/v)	7.5	Agar	[15-16]	TAC cleaned off most of the surface deposits and removed corrosion products, but also removed the thinnest parts of the painted layer of the Messerschmitt object. TAC had limited effectiveness but did not modify the paint
EthyleneDiamineTetraAcetic Acid (EDTA) (0.5 M)	8	Agar or Xanthan	[6, 17]	EDTA cleaned off most of the surface deposits and removed corrosion products, the surface was clean after a minimum of 6 ten-minute gel applications. EDTA solution was the most effective but can slightly damage paint.
Sodium Metalicate (2 % w/v)	9	Xanthan	[17]	Sodium metasilicate had little effect on corrosion products even after 60 minutes of treatment. On the painted surface, sodium metasilicate yielded the best results so far as it removed exogenous deposits without inducing any discoloration of the painted surface
Ammonium sulphate (0.125 M) + Ammonia (NH_3) (0.25 M)	9.6	Xanthan	[9]	The ammonium sulphate and ammonia mixture worked well but yielded a matte finish Ammonium sulphate with aqueous ammonia dissolved paint remains and is not recommended for painted surfaces.
Cationic Resin by CTS (120H Cation)	2.9	Only with water	[18]	120H Cationic Resin also gave excellent results. However, there are limitations due to its fast reaction time and it is not suitable for larger surfaces

Finally, different cleaning techniques were tested: mechanical techniques and chemical treatments applied by gel. On corroded surfaces, the best results were obtained by blasting with vegetal abrasive, or by applying EDTA gel. On painted surfaces, the best results were obtained with chemical treatments. The choice of the active agent depended on which compounds were to be removed. When the paint strongly adhered, mechanical techniques, like blasting with vegetal abrasive or brushing with water, also gave very good results.

Because objects tested in WP 3 present similar materials and corrosion issues and that they could be directly relates to the choice of Spitfire treatment, the results of previous testing were employed on the Spitfire Mk VII MB887 wing fragments. Thus, for the parts of the Spitfire wing with residues of paint, the selected treatment solution was TAC.

Treatment choices for the Spitfire Mk VII MB887 wing fragment

The first step was to clean the internal area, removing any sediment, soil, sand, concretions and vegetation still present. Micro-suction enabled most of the various deposits to be extracted. After preliminary cleaning, the object gained considerably in terms of legibility. It was then necessary to consolidate the most severely damaged parts of the structure. For those parts that were exfoliating, an initial, in-depth consolidation was made with Paraloid B44 at 15 % w/v in acetone, then a second consolidation on the surface with Paraloid B44 at 30 % w/v in acetone. The front spar was lined with fiberglass using Paraloid B72 at 30 % or 60 % w/v in acetone. It was necessary to fill some of the internal parts to stabilize all the elements and restore the overall appearance of the object. Fills were made of Paraloid B72 (at 60 % or 70 % w/v in acetone) loaded with glass microspheres and pigments. Marine concretions were removed from ferrous parts by mechanical techniques, mainly with a rotation system, micro engraver or micro chisel. On structural Al alloy parts, mechanical techniques (sandblasting) were generally sufficient. The removal of concretions was finalized with a cotton compress impregnated with nitric acid at 10 % w (pH=1) for 30 seconds, then the surface was rinsed abundantly.

For the cleaning of the wing skin, which presented paint residue, aluminium corrosion products and rust stains, a first round of chemical cleaning was employed with a solution of TAC at 5 % w/v applied by Agar gel to 3 % w/v. Compared to other chemical agents, TAC was more efficient in removing dirt and was less aggressive. The gel was sprayed hot, in line with a protocol determined for application to large surfaces [19]. Three 20-minute applications were necessary to remove dirt and reduce rust stains (Figure 7). Cleaning of the wing skin was followed by blasting with vegetal abrasive to homogenize the surface.

The last part of the treatment which will focus on application of a protective coating and exhibition of the wing fragment is still in progress is scheduled for completion in early 2024.

In order to select the most suitable coating, we will use the results of WP5 which will specifically address coatings. The surface protection chosen for the wing will need to ensure treatment compatibility and reversibility.

The study of the exhibition system is also still in progress. The following specifications for display have been given to the stakeholders:

- The object must be mounted in such a way as to reinforce the structure and enable technical interpretation of the object;
- The interior surface must be accessible to enable long-term dusting and maintenance;
- The safety of the public must be ensured and clear information provided to help them understand the object;
- It must include a memorial to the pilot James Atkinson.

Figure 7. Mechanical cleaning: *a)* before; *b)* after treatment; *c)* consolidation; and chemical cleaning with TAC 5 % w/v applied with Agar gel to 3 % w/v by spray: *d)* removal of the gel; *e)* surface before cleaning; *f)* surface after cleaning.

Conclusions

This object epitomizes the wide range of issues related to technical and archaeological heritage. The historical and technical studies of the wing fragment highlight its considerable significance in terms of heritage and historical, emotional, aesthetic, scientific and technical value. The conservation project has also enabled the development of innovative cleaning techniques for Al alloys. Established mechanical cleaning techniques were coupled with chemical cleaning. The next conservation step for the preservation of the wing fragment is the surface protection of the aluminum alloy components. Tests will be carried out in the context of the PROCRAFT to select the most effective protection. The object will then be exhibited locally in Britanny (France) as a memorial to the pilot.

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