ANALYSIS OF ALTERNATIVES

and

SOCIO-ECONOMIC ANALYSIS

Complete version

Legal name of applicant(s):	Boeing Distribution (UK) Inc. (CT) Indestructible Paints Ltd (CT) MacDermid Performance Solutions UK Ltd (CT) Wesco Aircraft EMEA Ltd (CT, SD)
Submitted by:	Wesco Aircraft EMEA Ltd on behalf of the Aerospace and Defence Chromates Reauthorisation Consortium (ADCR)
Date:	February 2023
Substance:	- Chromium trioxide (includes "Acids generated from chromium trioxide and their oligomers", when used in aqueous solutions) - Sodium dichromate
Use title:	Formulation of mixtures with soluble Cr(VI) compounds for use in aerospace and defence industry and its supply chains for surface treatments
Use number:	1

Note

This submission includes no confidential information declared in this document. All information contained in this document can be made public. There is no accompanying document which provides confidential information, as a result there are no justifications for claiming any information confidential.

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Abbreviations

ADCR – Aerospace and Defence Chromates Reauthorisation

A&D – Aerospace and Defence

AfA – Application for Authorisation

AoA – Analysis of Alternatives

AoG – Aircraft on the Ground

BCR – Benefit to Cost Ratio

BtP – Build-to-Print manufacturer

CCC – Chemical Conversion Coating

CCST – Chromium VI Compounds for Surface Treatment

CMR – Carcinogen, Mutagen or toxic for Reproduction

Cr(VI) – Hexavalent chromium

CSR – Chemical Safety Report

CT – Chromium trioxide

CTAC – Chromium Trioxide Authorisation Consortium

DtB – Design-to-Build manufacturer

DtC – Dichromium tris(chromate)

EASA – European Aviation Safety Agency

EBITDA – Earnings before interest, taxes, depreciation, and amortization

ECHA – European Chemicals Agency

EEA – European Economic Area

ESA – European Space Agency

GCCA – Global Chromates Consortium for Authorisation

GDP – Gross domestic product

GOS – Gross operating surplus

GVA – Gross value added

ICAO – International Civil Aviation Organisation

MoD – Ministry of Defence

MRL – Manufacturing readiness level

MRO – Maintenance, Repair and Overhaul

NADCAP – National Aerospace and Defence Contractors Accreditation Program

NATO – North Atlantic Treaty Organisation

NUS – Non-use scenario

OELV – Occupational Exposure Limit Value

OEM – Original Equipment Manufacturer

RAC – Risk Assessment Committee

REACH – Registration, Evaluation, Authorisation and restriction of Chemicals

RR – Review Report

SC – Sodium chromate

SD – Sodium dichromate

SEA – Socio Economic Analysis

SEAC – Socio Economic Analysis Committee

SME – Small and medium-sized enterprises

SVHC – Substance of Very High Concern

T&E – Testing and Evaluation

TRL – Technology Readiness Level

UK – United Kingdom

WCS – Worker contributing scenario

Glossary

Term	Description
Active Corrosion Inhibition	The ability of a corrosion protection system to spontaneously repair small amounts of chemical or mechanical damage that exposes areas of metal without any surface protection ("self-healing properties"). Active corrosion inhibition can be provided by soluble corrosion inhibitors.
Adhesion promotion	The ability of the treatment to improve and maintain the adhesion of subsequent layers such as paints, primers, adhesives, and sealants. It also includes the adhesion of the coating to the substrate.
Aeroderivative	Parts used in power generation turbines used to generate electricity or propulsion in civil and defence marine and industrial applications that are adapted from the design/manufacturing processes and supply chains that produce parts for the aerospace industry. Typical applications include utility and power plants, mobile power units, oil and gas platforms and pipelines, floating production vessels, and for powering marine/offshore vessels such as Naval warships.
Aerospace	Comprises the civil and military aviation, and space industries.
Aerospace and Defence (A&D)	Comprises the civil and military aviation, space industries and the public organisations and commercial industry involved in designing, producing, maintaining, or using military material for land, naval or aerospace use.
Aircraft	A vehicle or machine able to fly by gaining support from the air. Includes both fixed-wing and rotorcraft (e.g. helicopters).
Airworthiness	Airworthiness is defined by the International Civil Aviation Organisation as "The status of an aircraft, engine, propeller or part when it conforms to its approved design and is in a condition for safe operation". Airworthiness is demonstrated by a certificate of airworthiness issued by the civil aviation authority in the state in which the aircraft is registered, and continuing airworthiness is achieved by performing the required maintenance actions.
Airworthiness Authority	The body that sets airworthiness regulations and certifies materials, hardware, and processes against them. This may be for example the European Union Aviation Safety Authority (EASA), the Federal Aviation Administration (FAA), or national defence airworthiness authorities.
Airworthiness regulations	Set performance requirements to be met. The regulations are both set and assessed by the relevant airworthiness authority (such as EASA or national Ministry of Defence (MoD) or Defence Airworthiness Authority).
Alternative	Test candidates which have been validated and certified as part of the substitution process.
Article	An object which during production is given a special shape, surface or design which determines its function to a greater degree than does its chemical composition.
Assembly	Several components or subassemblies of hardware which are fitted together to make an identifiable unit or article capable of disassembly such as equipment, a machine, or an Aerospace and Defence (A&D) product.
Aviation	The activities associated with designing, producing, maintaining, or flying aircraft.
Benefit-Cost Ratio (BCR)	An indicator showing the relationship between the relative costs and benefits of a proposed activity. If an activity has a BCR greater than 1.0, then it is expected to deliver a positive net present value.
Build-to-Print (BtP)	Companies that undertake specific processes, dictated by the OEM, to build A&D components.
Certification	The procedure by which a party (Authorities or MOD/Space customer) gives written assurance that all components, equipment, hardware, services, or processes have satisfied the specific requirements. These are usually defined in the Certification requirements.

Term	Description
Coefficient of friction	Friction is the force resisting the relative motion of solid surfaces sliding against each other. The coefficient of friction is the ratio of the resisting force to the force pressing the surfaces together.
Complex object	Any object made up of more than one article.
Component	Any article regardless of size that is uniquely identified and qualified and is either included in a complex object (e.g. frames, brackets, fasteners and panels), or is a complex object itself (e.g. an assembly or sub-system).
Compound annual growth rate	The mean annual growth rate of an investment over a specified period of time, longer than one year.
Corrosion protection	Means applied to the metal surface to prevent or interrupt chemical reactions (e.g. oxidation) on the surface of the metal part leading to loss of material. The corrosion protection provides corrosion resistance to the surface.
Defence	Comprises the public organisations and commercial industry involved in designing, producing, maintaining, or using military material for land, naval or aerospace use.
Design	A set of information that defines the characteristics of a component (adapted from EN 13701:2001).
Design owner	The owner of the component/assembly/product detailed design. For Build-to-Print designs, the design owner is usually the OEM or military/space customer. For Design-to-Build, the supplier is the design owner of the specific hardware, based on the high-level requirements set by the OEM (as their principal).
Design-to-Build (DtB)	Companies which design and build components. Also known as “Build-to-Spec".
Embrittlement	The process of becoming degraded, for example loss of ductility and reduction in load-bearing capability, due to exposure to certain environments.
Fatigue	Progressive localised and permanent structural change that occurs in a material subjected to repeated or fluctuating strains at stresses less than the tensile strength of the material. The “permanent structural change” is in the form of microcracks in the crystal structure that can progressively lead to potentially catastrophic macro-cracking and component failure.
Flexibility	The ability to bend easily without breaking or permanently deforming.
Formulation	A mixture of specific substances, in specific concentrations, in a specific form.
Formulator	Company that manufactures formulations (may also design and develop formulations).
Gross Domestic Product (GDP)	The standard measure of the value added created through the production of goods and services in a country during a certain period. As such, it also measures the income earned from that production, or the total amount spent on final goods and services (less imports).
Gross Operating Surplus	Equivalent to economic rent or value of capital services flows or benefit from the asset.
Gross Value Added	The value of output less the value of intermediate consumption; it is a measure of the contribution to GDP made by an individual producer, industry or sector.
Hardness	Ability of a material to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material’s resistance to deformation due to other actions, such as cutting, abrasion, penetration and scratching.
Heat resilience	The ability of a coating or substrate to withstand repeated cycles of heating and cooling and exposure to corrosive conditions. Also known as cyclic heat-corrosion resistance.
Hot corrosion resistance	The ability of a coating or substrate to withstand attack by molten salts at temperatures in excess of 400°C.
Industrialisation	The final step of the substitution process, following Certification. After having passed qualification, validation and certification, the next step is to industrialise the qualified material or process in all relevant activities and operations of production, maintenance, and the supply chain. Industrialisation may also be referred to as implementation.
Layer thickness	The thickness of a layer or coatings on a substrate.
Legacy parts	Any part that is already designed, validated, and certified by Airworthiness Authorities or

Term	Description
	for defence and space, or any part with an approved design in accordance with a defence or space development contract. This includes any part in service.
Material	The lowest level in the system hierarchy. Includes such items as metals, chemicals, and formulations (e.g. paints).
Maintenance, Repair and Overhaul (MRO)	The service of civilian and/or military in-service products. Term may be used to describe both the activities themselves and the organisation that performs them.
NACE	The Statistical Classification of Economic Activities in the European Community. It is part of the international integrated system of economic classifications, based on classifications of the UN Statistical Commission (UNSTAT), Eurostat as well as national classifications.
NADCAP	National Aerospace and Defence Contractors Accreditation Program which qualifies suppliers and undertakes ISO audits of their processes.
Net Present Value	Valuation method to value stocks of natural resources. It is obtained by discounting future flows of economic benefits to the present period.
Original Equipment Manufacturer (OEM)	Generally large companies which design, manufacture, assemble and sell engines, aircraft, space, and defence equipment (including spare parts) to the final customer. In addition, an OEM may perform MRO activities.
Part	Any article or complex object.
Pickling	The removal of surface oxides and small amounts of substrate surface by chemical or electrochemical action.
Present Value	The discounted sum of all future debt service at a given rate of interest. If the rate of interest is the contractual rate of the debt, by construction, the present value equals the nominal value, whereas if the rate of interest is the market interest rate, then the present value equals the market value of the debt.
Pre-treatment	Pre-treatment processes are used, prior to a subsequent finishing treatment (e.g. chemical conversion coating, anodising), to remove contaminants (e.g. oil, grease, dust), oxides, scale, and previously applied coatings. The pre-treatment process must also provide chemically active surfaces for the subsequent treatment. Pre-treatment of metallic substrates typically consists of cleaning and/or surface preparation processes.
Producer surplus	Represents the gain to trade a producer receives from the supply of goods or services less the cost of producing the output (i.e. the margin on additional sales).
Proposed candidate	A formulation in development or developed by a formulator as a part of the substitution process for which testing by the design owner is yet to be determined. In the parent applications for authorisation, this was referred to as a ‘potential alternative’.
Qualification	1. Part of the substitution process following Development and preceding Validation to perform screening tests of test candidate(s) before determining if further validation testing is warranted 2. The term qualification is also used during the industrialisation phase to describe the approval of suppliers to carry out suitable processes.
Requirement	A property that materials, components, equipment, or processes must fulfil, or actions that suppliers must undertake.
Resistivity	Property that quantifies how a given material opposes the flow of electric current. Resistivity is the inverse of conductivity.
Social Cost	All relevant impacts which may affect workers, consumers and the general public and are not covered under health, environmental or economic impacts (e.g. employment, working conditions, job satisfaction, education of workers and social security).
Specification	Document stating formal set of requirements for activities (e.g. procedure document, process specification and test specification), components, or products (e.g. product specification, performance specification and drawing).
Standard	A document issued by an organisation or professional body that sets out norms for technical methods, processes, materials, components, and practices.
Sub-system	The second highest level in the system hierarchy. Includes such items as fuselage, wings,

Term	Description
	actuators, landing gears, rocket motors, transmissions, and blades.
Surface morphology	The defined surface texture of the substrate.
System	The highest level in the system hierarchy. Includes such items as the airframe, gearboxes, rotor, propulsion system, electrical system, avionic system, and hydraulic system.
System hierarchy	The grouping/categorisation of the physical elements that comprise a final product (such as an aircraft), according to their complexity and degree of interconnectedness. Comprises materials, parts/components, assemblies, sub-systems, and systems.
Temperature resistance	The ability to withstand temperature changes and extremes of temperature.
Test candidate	Materials which have been accepted for testing or are currently undergoing testing by a design owner, as a part of the substitution process. In the parent applications for authorisation, this was referred to as a 'candidate alternative'.
Type certificate	Document issued by an Airworthiness Authority certifying that an Aerospace product of a specific design and construction meets the appropriate airworthiness requirements.
Validation	Part of the substitution process following Qualification and preceding Certification, to verify that all materials, components, equipment, or processes meet or exceed the defined performance requirements.
Value of statistical life	Values the impact of risks to the length of life.
Verification	The process of establishing and confirming compliance with relevant procedures and requirements.
Wear resistance	The ability of a surface to withstand degradation or loss due to frictional movement against other surfaces.
Sources: GCCA and ADCR consortia	

DECLARATION

We, the Applicants, are aware of the fact that further evidence might be requested by HSE to support information provided in this document.

Also, we request that the information blanked out in the "public version" of the Analysis of Alternatives and Socio-economic analysis is not disclosed. We hereby declare that, to the best of our knowledge as of today 8 February 2023 the information is not publicly available and, in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to this information without our consent or that of the third party whose commercial interests are at stake.

Signature: Date: 8 February 2023

mazin.badri@incora.com

08/02/2023

SES Simple electronic signature
Signed on Skribble.com

1 Summary

This combined AoA/SEA uses some terms in a manner specific to the aerospace and defence sector. Please see the glossary for explanations of the specific meaning of commonly used words, such as component, and other technical terms within the context of this report.

1.1 Introduction

The Aerospace and Defence Chromates Reauthorisation (ADCR) Consortium on behalf of the applicants has developed several review reports and new applications. These review reports or new applications cover all uses of soluble chromates considered to be relevant by the ADCR consortium members. Although formally they are upstream applications submitted by manufacturers, importers or formulators of chromate-containing chemical products, the applications are based on sector-specific data and detailed information obtained from actors throughout the supply chain.

For the purposes of this document, the term 'aerospace and defence' comprises the civil aviation, defence/security and space industries, as well as aeroderivative products. The aerospace and defence (A&D) industry has been working towards the substitution of Cr(VI) across various uses for the past 25 to 30 years. Although there have been numerous successes and levels of use have decreased significantly, the specific use of the hexavalent chromium compounds[1] is still required for many surface treatment activities which are critical to both flight safety and to military mission readiness, and hence to society. The socio-economic impacts of a refused authorisation are therefore significant not just for the sector but also for the EEA and UK societies and economies more generally. Furthermore, at the EU level, the A&D sector is one of the 14 sectors highlighted by the EU's New Industrial Strategy[2] as being important to innovation, competition and a strong and well-functioning single market.

This review report or new application for authorisation is aimed at ensuring that formulation of the mixtures used by the A&D value chain can continue in the EEA/UK until alternatives to the chromates are qualified and certified in the manufacture, maintenance, repair and overhaul of A&D components and final products. These mixtures are essential to the following surface treatment activities for which the ADCR is also seeking authorisation for up to 12 years after the end of the current review period:

- Anodise sealing
- Anodising
- Chemical conversion coating
- Chromate rinsing after phosphating
- Electroplating
- Formulation
- Inorganic finish stripping

[1] Review Reports are also being submitted by the ADCR covering eleven other uses of the chromates in formulation and other specific surface treatment activities as more narrowly defined by the ADCR.

[2] https://op.europa.eu/en/publication-detail/-/publication/52904a0b-ae95-11eb-9767-01aa75ed71a1/language-en

- Passivation of (non-Al) metallic coatings
- Passivation of stainless steel
- Pre-treatments: deoxidising, pickling, etching and/or desmutting
- Slurry coating.

Although there have been alternatives and levels of use of chromates have decreased significantly, the use of chromium trioxide, sodium dichromate, potassium dichromate and sodium chromate in formulations used by the aerospace and defence sector (A&D) is still required as part of the surface treatments used to produce large numbers of components and final products. This document provides the analysis of alternatives and socio-economic analysis to support the continued use of these chromates in:

- *"Formulation of mixtures with soluble Cr(VI) compounds for use in aerospace and defence industry and its supply chains for surface treatments".*

Formulation forms a first step in all supply chains relevant for the ADCR consortium. The continued use of formulations covered by this assessment is essential until alternatives (formulations, substances or techniques) are developed, tested, qualified and certified for use in the manufacture of those components and final products. Their use is critical to ensuring flight safety and military mission readiness, and hence to society. The socio-economic impacts of a refused authorisation are therefore significant not just for the sector but also for the EEA and UK economies more generally.

The applicants are members of this consortium, acting on behalf of their downstream user members which include both formulators and companies within the A&D supply chain.

1.2 Availability and suitability of alternatives

At the formulation stage, the chromates have no (separate) function, hence no analysis of alternatives can be provided.

The function played by the end mixtures containing one or more of the four chromates developed for use by the A&D sector is described in the review reports and new applications submitted for the eleven uses of chromates in formulation and other surface treatment uses listed above. The availability of alternative mixtures, in terms of their technical feasibility, economic feasibility and availability is also discussed for each use in its respective review report and new application.

As detailed in the combined AoA/SEAs supporting each of the surface treatment uses, there are several factors that affect the availability and suitability of alternatives to the downstream users of the mixtures using one or more of the four chromates. Of key importance is that the adoption of alternatives is subject to strict regulatory requirements to ensure the continued airworthiness and safety and reliability of aerospace and defence final products. These requirements generate additional, complex testing and development, qualification, certification and industrialisation activities that have to be carried out component by component to ensure the continued airworthiness of aircraft and the safety and reliability of defence equipment (including air, naval and land-based systems).

As a result, formulation involving the chromates is still required as there are no alternatives to the use of the resulting mixtures which can be considered "generally available" following the European

Commission's definition[3]. Obtaining such certification across hundreds of components is a time-consuming process, given the strict testing regimes that must be adhered to achieve the qualification, validation and certification of components using an alternative.

These requirements which must be met by the downstream users of the formulations are detailed further in Section 3 of this document.

1.3 Socio economic benefits from continued use

The continued use of the four chromates in the formulation of mixtures over the requested 12 year review period will confer significant socio-economic benefits to the formulators and their downstream users in the A&D industry, which include civil aviation, military users (air, land and sea), emergency services and aeroderivative products. It will also protecting the wider economic and employment benefits delivered by the A&D industry in the EEA/UK.

The socio-economic impacts of a refused authorisation are quantified here in terms of the potential lost profits to formulators and impacts on employment at their operations. These impacts are not taken into account in the SEAs prepared to support each of the ten surface treatment uses of formulated chromate mixtures, in order to minimise the potential for double-counting of profit losses.

The estimated socio-economic benefits formulation of mixtures with soluble Cr(VI) compounds for use in aerospace and defence industry and its supply chains for surface treatments are as follows:

- Lost profits: €7.5 million in the EEA and €370,000 (£319,000) in the UK;
- Social costs of unemployment: €13.4 million in the EEA and €836,000 (£731,000) in the UK.

These benefits are very small in comparison to the benefits from the continued use of the mixtures produces by the six companies involved in formulation to the A&D industry. The SEAs submitted by the ADCR as part of the review reports supporting the ten surface treatments in which the mixtures are used highlight the value of their continued availability. Lost profits due to the loss of the mixtures would equate to over €100 billion in the EEA and tens of £ billions in the UK.

This is because a decision not to grant a re-authorisation for formulation while granting re-authorisations for the ten downstream surface treatment uses would disrupt the market. It could result in transfer of formulation to non-EEA countries, however, this would depend on the six companies involved in formulation being willing to invest in new facilities. Given that use of the same or similar Cr(VI) mixtures are certified in the manufacture of components and end products in other countries and low economic value of these products to the formulators, it is unlikely that EEA/UK formulators would relocate.

Furthermore, A&D companies would have to re-certify any mixtures produced at a new location for use in the manufacture, maintenance and repair of their components and end products; they would also have to re-certify use of mixtures should there be any changes occurring in the source of the

[3] As defined with respect to the "legal and factual requirements of placing on the market" in the EC note of 27 May, 2020, available at: 5d0f551b-92b5-3157-8fdf-f2507cf071c1 (europa.eu)

chromate substances used in formulation or any changes to the manufacturing process (even if this is only the location). As this would have to be carried out across thousands of components, it would essentially translate to a cessation in the production of components and the manufacturing of final products, leading to lost profits from a cessation of activities in the EEA/UK. Re-certification at this scale would take years.

Given that use of the same or similar Cr(VI) mixtures are certified in the manufacture of components and end products in other countries, it is unlikely that A&D companies would go through such re-certification while at the same time incurring the costs of qualifying and certifying alternatives.

The most plausible non-use response of A&D companies, therefore, is to relocate significant portions of their manufacturing activities outside the EEA/UK to countries where use of certified Cr(VI) mixtures remains feasible. This would result in a loss of turnover, profits and jobs to the EEA/UK. It has been assumed in this SEA and the SEAs that support the review reports for authorisation of the ten main surface treatments that such impacts would only occur over a period of two years (ECHA's default time period for estimating surplus losses), but in reality they would extend far longer into the future, due to the loss of such an important manufacturing base. These impacts would occur over several years, given that the most response of A&D companies to such a scenario is to relocate significant portions of their manufacturing activities outside the EEA/UK to countries where use of certified mixtures remains feasible.

Overall, the benefits to A&D downstream users and the EEA/UK economies from the continued authorisation of formulation equate to hundreds of billions of Euros in profits and avoided costs of unemployment from the continued availability of Cr(VI) mixtures for surface treatment and subsequent manufacturing of aerospace and defence products.

1.4 Residual risk to human health from continued use

The A&D sector is planning on substitution of the chromate-based formulations over the next 12 years (the longest requested year review period across the 10 surface treatment uses). As a result, the quantity of the chromates use in formulation activities should decline over this period, as should the levels of exposures to workers undertaking formulation and to humans via the environment from their use at the six sites.

Risks to workers have been estimated based on the use of exposure monitoring data, supplemented by modelling data as appropriate. Across the four EEA sites and two UK sites where formulation of mixtures take place, a total of 52 workers (36 in the EEA and 16 in the UK) are working with Cr(VI) and may be potntially exposed.

Exposures for humans via the environment have been calculated for the local level only. Based on the population density of the different countries in which formulation takes place, an estimated 3,069 people in the EEA and 2,664 people in the UK are calculated as potentially being exposed to Cr(VI) in relevant vicinity of the sites.

The predicted number of cancer cases per annum and the annualised economic value of these social costs for both workers and humans via the environment are:

- EEA: 0.011 fatal cancers and 0.003 non-fatal cancers over the 12-year review period, at a total social cost of €16,500.

- UK: 0.006 fatal cancers and 0.001 non-fatal cancers over the 12-year review period, at a total social cost of €8,141 (£7,000).

1.5 Comparison of socio-economic costs and benefits

The ratios of the benefits of continued use to formulators to the residual risks to human health are as follows for the EEA and UK respectively:

- EEA: 1,263 to 1, where economic and social impacts are assessed over 2 years and residual risks over 12 years; and
- UK: 136 to 1, again over a 2 year period for economic and social costs and 12 years for residual risks to workers and humans via the environment.

The above estimates represent a significant underestimate of the actual net benefits from the continued use of chromium trioxide, sodium dichromate, potassium dichromate and sodium chromate in formulation activities in the EEA and of chromium trioxide and sodium dichromate in the UK. It only encompasses the benefits that could readily be quantified and monetised and it does not include any benefits to downstream users in the A&D value chain to ensure no double-counting of impacts in combination with the other review reports being submitted by the ADCR. The true benefit-cost ratios would also encompass:

- The avoided profit losses and social costs of unemployment due to the ability of downstream A&D companies and military forces to continue to undertake the ten surface treatments that rely on the Cr(VI) mixtures that are the products of the formulation activities within scope of this review report. These avoided losses equate to hundreds or tens of billions of pounds sterling (EEA and UK respectively) over just a two year period;

- The avoided impacts on air transport – both passenger and cargo – across the EEA and UK that would arise due to stranded aircraft on the ground (AoG), reductions in available aircraft, increased flight costs, etc.;

- The avoided impacts on society more generally due to impacts on air transport and the wider economic effects of the high levels of unemployment within a skilled workforce, combined with the indirect and induced effect from the loss of portions of the A&D sector from the EEA and UK as they either cease some activities or relocate relevant operations; and

- The avoided economic and environmental costs associated with increased transporting of components in and out of the EEA/UK for maintenance, repair and overhaul (whether civilian or military) and production activities.

1.6 Factors to be considered when defining the operating conditions, risk management measures, and/or monitoring arrangements

A range of factors should be taken into account when considering the need for additional risk management measures and/or monitoring requirements:

- Occupational exposure monitoring requirements were placed on downstream users, including formulators, as part of the granting of the parent authorisations. The affected companies have responded to these requirements by increasing the level of monitoring carried out, with this including increases in expenditure on worker monitoring and adaptations to the way in which monitoring was previously carried out.

- A Binding Occupational Exposure Limit Value (OELV) was introduced under EU Directive 2004/37/EC that will become more stringent after January 17th, 2025; this Binding OELV was recommended by the Tripartite Advisory Committee on Safety and Health based on consensus and will provide an additional level of protection for workers involved in formulation.

- The formulators are working with the A&D downstream users to reduce the volume of chromates used in surface treatment activities, and the A&D companies are implementing substitution plans across all current uses, as indicated in the Substitution Plans included in the review reports submitted by the ADCR supporting the ten surface treatments in which use of the chromates remains essential.

- The requested review period is 12 years, with the demand for the formulated mixtures expected to reduce over this period as substitution takes place. As a result, lifetime excess cancer risks to workers involved in formulation activities will reduce over time, as will risks to the general public which are already below the target level set by the Risk Assessment Committee to support very long review periods ($1x10^{-6}$ for the general public).

1.7 Factors to be considered when assessing the duration of a review period

These include the following, which result in the need for longer (12 years) than normal (7 years) review periods:

- The applicants' downstream users face investment cycles that are demonstrably very long, as recognised in various European Commission reports. Final products in the A&D sector can have lifespan of over 50 years (especially military equipment), with there being examples of contracts to produce parts for out-of-production final products extending as long as 35 years. Maintenance, repair and overhaul companies (MROs) as well as Ministries of Defence (MoDs) require the ability to continue servicing older, out-of-production but in-service aircraft and military equipment (including air, land and sea). The inability to continue servicing such final products will not only impact upon civil aviation but also emergency vehicles and importantly operationally critical military equipment.

- The costs of moving to alternatives are high for the downstream users of the formulations, not necessarily due to the cost of the alternatives but due to the strict regulatory requirements that must be met to ensure airworthiness and safety for military use. The requirements placed on A&D companies mandate the need for testing, qualification, validation and certification of components using the alternatives, with this having to be carried out for all components and then formally implemented through changes to design drawings and maintenance manuals. In some cases, this requires retesting of entire end products for extensive periods of time, which is not only costly but may also be infeasible (due to a lack of testing facilities, age of available test vehicles (engines, aircraft, defence equipment, etc.). On a cumulative basis, the major OEMs and DtB companies that act as the design authorities could not afford to undertake action across the range and numbers of components that still require the qualification, certification and industrialisation of the alternatives at the same time.

- **The strict regulatory requirements that must be met by A&D companies in the manufacture of components and final products generate additional, complex requalification, recertification, industrialisation activities**, to ensure the continued airworthiness of aircraft and the safety and reliability of defence equipment (including air, naval and land-based systems). These requirements mean that there is no simple or single drop-in replacement for chromium trioxide in electroplating processes, which can be considered to be "generally available" following the European Commission's definition[4]. The A&D industry has been undertaking R&D into alternatives for the past 30 years. This includes participation in research initiatives partially funded by the European Commission and national governments. Considerable technical progress has been made in developing, validating qualifying and certifying components for the use of alternatives, however, it is not technically nor economically feasible for the sector as a whole to have achieved full substitution within a seven-year period. As a result, sufficient time for the continued use of the chromates in formulation of the mixtures used by A&D companies is required to enable these downstream users fully implement alternatives through the value chain once the alternatives have been certified.

- Even then, **it may not be feasible for military MROs to move completely away from the use of Cr(VI) mixtures due to mandatory maintenance, repair and overhaul requirements**. MROs must wait for OEMs or MoDs to update Maintenance Manuals with an appropriate approval for each treatment step related to the corresponding aircraft components or military hardware. The corresponding timescale for carrying out such updates varies and there can be significant delays while OEMs/MoDs ensure that substitution has been successful in practice.

- In this respect**, it is important to note that the use of the four chromates in the formulation of mixtures is required (and may be required beyond 12 years) to ensure the operational capabilities of the military and the ability to comply with international obligations as partner nations at the EU level and in a wider field, e.g. with NATO**.

- **Given the above, an Authorisation for formulation of an appropriate length is critical to the continued operation of aerospace and defence manufacturing, maintenance repair**

[4] As defined with respect to the "legal and factual requirements of placing on the market" in the EC note of 27 May, 2020, available at: 5d0f551b-92b5-3157-8fdf-f2507cf071c1 (europa.eu)

and overhaul activities in the EEA/UK. The sector needs certainty to be able to continue operating in the EEA/UK using Cr(VI) mixtures until alternatives can be implemented. It is also essential to ensuring the uninterrupted continuation of activities for current in-service aircraft and defence equipment across the EEA/UK.

- As indicated in Section 5, **the socio-economic benefits from the continued formulation and use of Cr(VI) mixtures significantly outweigh the risks of continued use.** The European A&D sector is a major exporter of final products and is facing a growing market for both its civilian and defence products which it can only serve if it retains its current strong industrial and supply chain base in the EEA and UK. It will not be able to respond to this increased market demand if the continued use of the Cr(VI) mixtures is not authorised while work continues on developing, qualifying and certifying alternatives.

- Finally, the global nature of the aerospace and defence sector must be recognised. The EEA and UK A&D sector must ensure not only that it meets regulatory requirements in the EEA and UK, but also that it meets requirements in other jurisdictions to ensure that its final products can be exported and used globally.

2 AIMS AND SCOPE OF THE ANALYSIS

2.1 Introduction

2.1.1 The Aerospace and Defence Reauthorisation Consortium

This is an upstream application submitted by importers of the chromates and/or formulators of chromate-containing chemical products. It is an upstream application due to the complexity of the aerospace supply-chain, which contains many small and medium-sized enterprises (SME). The ADCR was specifically formed by the major European A&D companies to respond to this complexity and to benefit the entire supply chain, thereby minimizing the risk of supply chain disruption across the A&D sector. This includes ensuring that the industry's major OEMs and Design-to-Build companies are able to change sources of supply for the manufacture of components and parts; the importance of this type of risk minimization has become only too apparent due to the types of supply chain disruption that has arisen due to COVID-19.

This combined AoA and SEA provides an updated assessment from that presented in the parent Applications for Authorisation (AfA) for the purposes of this Review Report (RR). The scope includes all the soluble chromates – chromium trioxide, sodium dichromate, potassium dichromate and sodium chromate – relevant for formulation of mixtures products by ADCR consortium members who act as formulators, taking into account the needs of their supply chains. These chromate-based mixtures will impart different functions in their different uses, including improving corrosion resistance, promoting adhesion to subsequent layers (such as a primer), or also ensuring electrical conductivity.

The use of the formulated products is limited to those situations where they play a critical (and currently irreplaceable) role in meeting product performance, reliability, and safety standards, particularly those relating to airworthiness set by European Aviation Safety Agency (EASA). This is also true with respect to their use in defence, space and in aerospace derivative products, which include non-aircraft defence systems, such as ground-based installations or naval systems. Such products and systems must comply with numerous other requirements including those of the European Space Agency (ESA) and of national Ministries of Defence.

In addition, order to ensure consistency and continuity of global supply chains under UK REACH this document also covers the requirements of aerospace supply chains in the Great Britain.

2.1.2 Aims of the combined AoA and SEA document

Although the formulators covered by this review report have been successful in working with the A&D sector to implementing alternatives in some applications, the continued use of the chromates in formulations is required beyond the existing review period which expires in September 2024 for chromium trioxide, sodium dichromate, potassium dichromate and sodium chromate.

The downstream users supporting the ADCR consortium have no alternatives and must continue to rely on the use of the chromate-based mixtures until they have fully developed, qualified and certified alternatives for use in the manufacture of components and final products. These mixtures are essential to the delivery of a range of functions to the surface treatment processes in which they are used. In particular, they are fundamental and integral to preventing corrosion of critical aerospace components, forming part of an overall anti-corrosion system aimed at ensuring the on-going airworthiness of aircraft and safety and reliability of military products.

The aim of this combined AoA/SEA is to demonstrate:

- The technical and economic feasibility, availability, and airworthiness (i.e., safety) challenges in identifying an acceptable alternative to the use of the chromate-based mixtures, which does not compromise the functionality and reliability of the parts treated with formulated chemical products and which could be certified by OEMs and gain approval by the relevant aviation and military authorities across the globe;

- The efforts currently in place to progress potential alternatives through Technical Readiness Levels (TRLs), Manufacturing Readiness Levels and final validation/certification of suppliers to enable final implementation. This includes treatment of parts and assemblies for civilian and military aircraft and defence equipment that continue to be produced, as well as for maintenance, repair and overhaul of those products and as well as out-of-production civilian and military aircraft and defence equipment;

- The socio-economic impacts that would arise for the ADCR value chain and, crucially, for the EEA/UK more generally, if the applicants were not granted re-authorisations for the continued use of the chromates in formulation activities over an appropriately long review period; and

- The overall balance of the benefits of continued use of the chromates in formulation activities and risks to human health from the carcinogenic and reprotoxic effects that may result from exposures to the chromates from these activities.

2.2 The Parent Applications for Authorisation

This combined AoA and SEA covers the use of the following chromates in formulation:

• Chromium trioxide (includes “Acids generated from chromium trioxide and their oligomers", when used in aqueous solutions)	EC 215-607-8	CAS 1333-82-0
• Sodium dichromate	EC 234-190-3	CAS 10588-01-9
• Potassium dichromate	EC 231-906-6	CAS 7778-50-9
• Sodium chromate	EC 231-895-5	CAS 7775-11-3

These four chromates were granted authorisations for use in formulation to a range of upstream applicants, with Table 2-1 summarising the initial applications which act as the parent applications to this Review Report.

Each of the applicants is applying for the re-authorisation of formulation activities of the same scope as covered by their original application. This review report is not seeking to also act as a new application for authorisation by any of these applicants. Such new applications are being submitted separately.

Table 2–1: Overview of Initial Parent Applications for Authorisation					
Application ID/ authorisation number	**Substance**	**CAS #**	**EC #**	**Review report applicants**	**Parent Authorisation – Authorised Use**
0032-01 REACH/20/18/0, REACH/20/18/2 REACH/20/18/4	Chromium trioxide	1333-82-0	215-607-8	Various applicants (CTAC consortium)	Formulation of mixtures exclusively for uses REACH/20/18/7 to REACH/20/18/34
0043-01 REACH/20/5/0 REACH/20/5/2 23UKREACH/20/5/0	Sodium dichromate	10588-01-9	234-190-3	Various applicants (CCST consortium)	Use in formulation of mixtures intended exclusively for uses REACH/20/5/3, REACH/20/5/4, REACH/20/5/5, REACH/20/5/6, REACH/20/5/7 and REACH/20/5/8
0044-01 REACH/20/3/0	Potassium dichromate	7778-50-9	231-906-6	Brenntag Chemicals Distribution (Ireland) Ltd (CCST Consortium)	Formulation of mixtures intended exclusively for surface treatment of metals (such as aluminium, steel, zinc, magnesium, titanium, alloys), composites and sealings of anodic films for the aerospace sector in the surface treatment processes in which any key functionalities listed in the Annex is required
0099-01 REACH/19/32/0, REACH/19/32/1	Sodium chromate	7775-11-3	231-889-5	Various applicants (GCCA consortium)	Formulation of mixtures of sodium chromate for sealing after anodizing, chemical conversion coating, pickling and etching applications by the aerospace sector

2.3 Scope of the analysis

2.3.1 Brief overview of uses

2.3.1.1 Process description

This combined AoA-SEA covers the formulation of mixtures containing chromium trioxide, sodium dichromate, potassium dichromate and sodium chromate for use by the aerospace and defence industry and its supply chains. This use is performed in exclusively industrial settings at companies specialised in formulation activities. Their activities generally involve formulation of chromates for other sectors (in addition to the A&D supply chains) and includes formulation of mixtures not containing chromates. However, the respective portions vary from company to company. The share of the production of Cr(VI) products directed to the A&D supply chains also varies largely (3% to approx. 50% of the production at individual companies).

Typically, more than one of the four chromates may be used at a given site in parallel as part of the formulation of products. This includes their combined use in some formulation activities, for example, in mixtures produced for use in chemical conversion coatings produced for the A&D sector. As a result, exposure of workers and of humans via the environment will be to the combination of substances. Similarly, there will be an overlap in the economic impacts and losses in employment that would arise under the non-use scenario should continued use of only one or more of the chromates in formulation be refused.

Formulation of the four soluble chromates includes the preparation of aqueous solutions from the solid, neat substances or dilution of higher concentrated aqueous solutions (both processes with or without blending with additives). In addition, solid mixtures are prepared by blending with additives.

Solid chromates are supplied in drums or bags as crystals, flakes, or powders. Formulators blend or dissolve the chromates in closed mixing vessel at ambient temperature. This may vary from continuous production of a few special Cr(VI)-containing products in large amounts, to batchwise production of mixtures in low quantities. After mixing, the formulation is transferred to containers or other suitable packaging.

As noted previously, the chromates do not have an own functionality during formulation. The aim is to produce mixtures which fulfil the technical requirements of subsequent surface treatment processes.

2.3.1.2 Relationship to other uses

Mixtures (products) containing Cr(VI) compounds are manufactured to meet the high quality standards in the A&D supply chains. This step therefore is a prerequisite for achieving the required results in downstream surface treatments. This combined AoA/SEA covers the manufacture of products with chromium trioxide, sodium dichromate, potassium dichromate and sodium chromate relevant for all uses described in the other dossiers prepared by the ADCR consortium.

For the avoidance of doubt, the resulting mixtures are relevant to all of the following surface treatments:

- Pre-treatment activities including pickling, etching and deoxidising;
- Electroplating (hard chrome plating);
- Passivation of stainless steel;
- Passivation of non-Al metallic coatings;
- Anodising;
- Chemical conversion coating;
- Anodise sealing;
- Slurry coatings;
- Inorganic finish stripping; and
- Chromate rinsing after phosphating (only relevant to the EEA).

2.3.2 Temporal scope

Because of the lack of qualified and viable alternatives for the use of the mixtures containing one or more of the four soluble chromates in the manufacture, maintenance, repair and overhaul of A&D components, it is anticipated that formulation involving their use will be required for a further 12 years to develop, qualify, certify and industrialise alternatives across all components. Over this 12-year period, the temporal boundaries adopted in this assessment take into account:

- When human health, economic and social impacts would be triggered;
- When such impacts would be realised; and
- The period over which the continued use of the chromates would be required by the A&D industry as a minimum.

The impact assessment periods used in this analysis and the key years are presented in **Table 2–2.**

Table 2–2: Temporal boundaries in the analysis			
Present value year		2021	
Start of discounting year		2024	
Impact baseline year		2025	
Scenario	Impact type	Impact temporal boundary	Notes
"Applied for Use"	Adverse impacts on human health	12 years following a 20 year time lag	Based on the length of requested review period
"Non-use"	Loss of profit along the supply chain	12 years	Based on the length of requested review period
	Impacts on growth and GDP	12 years	Based on the length of requested review period
	Disruption to EU society due to impacts on civil, emergency and military aviation, as well as defence equipment	12 years	Based on the length of requested review period
	Loss of employment	1 to over 3 years	Average period of unemployment in the EEA (Dubourg, 2016)

2.3.3 The supply chain and its geographical scope

2.3.3.1 The ADCR Consortium

The ADCR is composed of 67 companies located in the EEA and Great Britain. This includes 17 companies that act as suppliers to the A&D industry, as importers, formulators and distributors. The remaining 50 members are active downstream users (OEMs, DtBs or BtPs) or are MRO providers (civilian or military) within the industry sector. ADCR membership also includes Ministries of Defence due to concerns over the loss of the availability of chromate formulations and substances for on-going maintenance and repair of military equipment.

Of the downstream user members, 24 comprise the leading OEMs, DtBs and MROs operating in the EEA and UK. These 24 companies operate across multiple sites in the EEA, as well as in Great Britain and more globally. It is the leading OEM and DtB companies that act as design owners and establish the detailed performance criteria that must be met by individual components and final products to ensure that airworthiness and military standards are met. A further 21 small and medium sized companies joined the ADCR in order to ensure the success of the consortium in re-authorising the continued use of the chromates and to share their information and knowledge. These companies are involved in BtP, DtB and MRO activities, sometimes acting as a combination of these.

All downstream user members of the ADCR are supporting this formulation review report, with this reflecting the importance of the chromate mixtures to the A&D value chain.

2.3.3.2 Producers of mixtures

The chromate substances are imported to the EEA by the applicants and are then sold to the formulators for use in production of the mixtures used by the A&D sector. Formulation is carried out at four sites in the EEA, with the relevant products listed in **Table 2–3**. These four operators are undertaking formulation activities in Germany (2 sites), Spain and the Netherlands.

Table 2–3: Products used in formulation

Product Type A	Solid CT (flakes), pure substance (100%); **52% Cr (VI)**
Product Type B	Solid SD (powder), pure substance (100%); **40% Cr (VI)**
Product Type C	Solid PD (powder), pure substance (100%); **35% Cr (VI)**
Product Type D	Solid SC (powder), pure substance (100%); **32% Cr (VI)**
Product Type E	Aqueous solution of CT as purchased (up to 50% CT (w/w)); **max. 26% (w/w) Cr (VI)**
Product Type F	Aqueous solution of SD as purchased (up to 70% SD (w/w)); **max. 28% (w/w) Cr (VI)**

Formulation involving all four chromates takes place in the EEA while only CT and SD are used in formulation activities carried out in the UK. It is important to note that the level of formulation that is undertaken in the EEA is more extensive than that taking place in the UK.

2.3.3.3 Downstream users of soluble chromate formulated mixtures

As already noted, the chromate-based mixtures produced by the formulators are used by the ADCR value chain in a range of different surface treatments, all of which are subject to their own review reports or new applications for authorisation under EU and/or UK REACH.

The end mixtures may contain only one of the above chromates or may contain a mixture of the chromates, e.g. be a mixture of chromium trioxide and sodium dichromate together with other ingredients. Each mixture will have been developed to meet a set of surface treatment requirements and may be used in more than one of the above surface treatments.

The mixtures are used in industrial settings, where their use may take place either by: Immersion of a metallic component into a bath or tank containing an aqueous solution containing the dissolved chromates (often together with acidic compounds); or via a more local treatment including brush, swab, wipe, or syringe. In some cases, use of the mixtures may involve a low level of automation, while in others there is a high level of automation.

Use of the mixtures is carried out by actors across all levels in the downstream value chain:

- Original equipment manufacturer (OEM) – generally large companies which design, manufacture, assemble and sell engines, aircraft, space and defence equipment to the final customer;
- Design-to-build[5] (DtB) manufacturers – companies which design and build components;
- Build-to-print (BtP) manufacturers – companies that undertake specific processes, dictated by their customers, involving use of chromates on components; and
- Maintenance, Repair and Overhaul (MRO) providers – companies or military sites that service civilian and military in-service products.

For the avoidance of any doubt, commercial aircraft, helicopter, spacecraft, satellite and defence manufacturers are involved in the supply chain, and in the use of chromate-containing mixtures in surface treatment of critical components essential to the manufacturing of their final products. It is important to note that companies may fit into more than one of the above categories, acting as an OEM, DtB, and MRO[6], where they service the components they designed and manufactured and which are already in use. Similarly, a company may fall into different categories depending on the customer and the component/final product.

The complexity of the downstream supply chain relationships is illustrated in **Figure 2-1** below, with this highlighting the global nature of these relationships and the interlinkages that exist between suppliers in different geographic regions.

5 Also referred to as "design and make" or "design responsible" suppliers
6 Also common are companies categorising themselves as a BtP and MRO

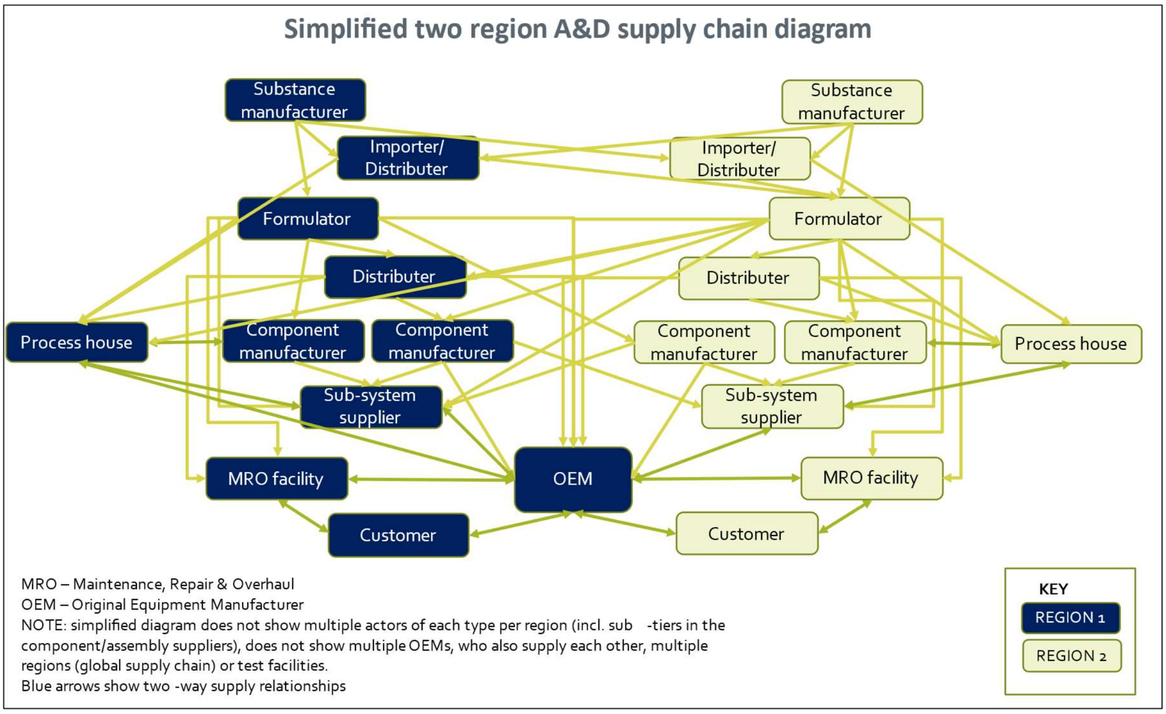

Figure 2-1: Complexity of supply chain roles and relationships within the A&D sector

Across all of the different surface treatment activities, it is estimated that there are likely to be the following numbers of downstream user sites of the chromate-containing mixtures in the EEA and the UK:

- Between 300 to 350 sites in the EEA;
- Between 20 and 50 sites in the UK (taking into account the more limited level of formulation carried out and hence range of mixtures applicable in the UK).

Note that the above figures exclude use of mixtures containing dichromium tris(chromate) which are not within scope of this review report.

2.3.3.4 Final Customers

The final actors within this value chain are customers of A&D final products manufactured, maintained or repaired using the Cr(VI)-based mixtures.

With respect to civil aviation, the global air transport sector employs over 10 million people to deliver in a normal year some 120,000 flights and 10 million passengers a day. In 2017, airlines worldwide carried around 4.1 billion passengers. They transported 56 million tonnes of freight on 37 million commercial flights. Every day, airplanes transport over 10 million passengers and around US$ 18 billion (€16 billion, £14 billion) worth of goods. Across the wider supply chain, subsequent impacts and jobs in tourism are made possible by air transport, assessments show that at least 65.5

million jobs and 3.6% of global economic activity are supported by the industry.[7] More specifically to Europe, in 2019 over 1 billion passengers travelled by air in the European Union, with net profits of over US$ 6.5 billion (€5.8 billion, £5.1 billion).[8] These benefits cannot be realised without the ability to undertake regular maintenance works and to repair and maintain aircraft as needed with replacement components manufactured in line with airworthiness approvals.

In 2020, total government expenditure on defence across the EU equated to 1.3% of GDP, with Norway spending around 2% of GDP.[9] Roughly 38% of this expenditure related to military aviation, with an uncertain but significant proportion also spent on non-aviation defence products that rely on the use of CCC, including naval systems, ground based radars, ground vehicles etc.

Focusing on military aircraft, the dynamics of aircraft development and the market are significantly different than for commercial aircraft. Military aircraft are extremely expensive and specialised projects. As a result, to have an effective military force, Ministries of Defence require equipment that is well-maintained and mission-ready. Although the in-service military fleet is expected to grow rapidly in the future, older aircraft and other equipment will continue to require more frequent scheduled maintenance to replace components that are reaching the end of their “service life”, which would not have needed replacing on younger aircraft. Upgrades will also be required to extend the service life of aging aircraft given the costs of new military aircraft. Maintenance of aircraft and products is already reported to face difficulties due to material obsolescence issues over the extremely long service lives of such hardware. A major issue is obtaining readily available components for the vast number of aircraft lying beyond their originally expected lifecycles.

2.4 Consultation

2.4.1 Consultation with Formulators

Information was gathered from formulators on the quantities of chromates used in formulation activities per annum, and on the locations of these activities and the number of workers involved in such activities. Data were also collected on the end mixtures produced and placed on the EEA and UK markets.

Only a minimal amount of socio-economic data was collected from the formulators, as losses in profits or employment for this group of companies is not what drives the requested re-authorisations or new applications for authorisation covered by this combined AoA/SEA. This is driven by the fact that the continued use of the end mixtures is currently essential in the A&D industry to meet certification requirements for the manufacture of components and end products. Until alternatives to the mixtures are certified in the manufacture of A&D components, and across all components, the use of the mixtures remains essential.

7 https://www.icao.int/annual-report-2020/Pages/the-world-of-air-transport-in-2020.aspx

8 https://www.statista.com/statistics/658695/commercial-airlines-net-profit-europe/

9 *Source:* Eurostat (gov_10a_exp)

2.4.2 Consultation with Downstream users

Consultation with ADCR members was carried out over a period from 2019 to 2022 to collect a range of data relevant to both the AoAs and SEAs prepared to support each of the ten surface treatment activities being supported by the Consortium.

Of relevance to this AoA-SEA is information gathered on the mixtures used by members across the different surface treatments, together with the associated volumes used. Data were also collected on the substitution process and the stringent requirements that are placed on A&D companies, as well as on the availability of alternatives to the chromate mixtures and on the progression of substitution plans across the different surface treatment uses of them.

The full extent of the consultation that was carried out is summarised in the review reports submitted for the ten surface treatment activities that rely on the use of the various chromate mixtures. The combined AoA-SEA documents for each surface treatment also detail the potential alternatives and the overarching sectoral substitution efforts together with the substitution plans being progressed by the OEM and DtB members of the ADCR. It is the timing of the substitution plans that determines the review period requested for the continued use of the chromates in formulation, as these companies are the “design owners” who will obtain the certifications required to enable alternatives to be used in the manufacture of components and final products.

3 Analysis of Alternatives

3.1 SVHC use applied for

For the avoidance of doubt, the hexavalent chromate (Cr(VI)) substances that are of relevance to the applied for use are:

• Chromium trioxide (includes “Acids generated from chromium trioxide and their oligomers", when used in aqueous solutions)	EC 215-607-8	CAS 1333-82-0
• Sodium dichromate	EC 234-190-3	CAS 10588-01-9
• Potassium dichromate	EC 231-906-6	CAS 7778-50-9
• Dichromium tris(chromate)	EC 246-356-2	CAS 24613-89-6

Only one of these chromates or a combination of these chromates may be used in formulation of the end mixtures that are essential to the A&D industry.

Formulation of Cr(VI)-containing mixtures includes the preparation of aqueous solutions from the solid, neat substances or dilution of higher concentrated aqueous solutions (both processes with or without blending with additives).

Solid mixtures are also prepared by blending with additives. Solid chromates are supplied in drums or bags as crystals, flakes, or powders. Formulators blend or dissolve the chromates in a closed mixing vessel at ambient temperature. After mixing, the formulation is transferred to containers or other suitable packaging.

Cr(VI)-containing mixtures are produced at industrial sites specialised in formulation activities. The manner in which the Cr(VI)-containing mixtures are produced at the different sites varies substantially and includes sites:

- producing continuously few special Cr(VI)-containing products in large amounts; and
- performing batchwise production of Cr(VI)-containing mixtures in low quantities.

At the formulation stage, the chromates have no (separate) function, hence no analysis of alternatives can be provided. The functions played by the mixtures developed for use by the A&D sector are described in the review reports and new applications submitted for the ten surface treatment uses listed in Section 2.3 above.

It should be noted that the same companies that undertake formulation using these chromates for A&D uses are also involved in research and development of non-chromate alternatives. The share of the production of Cr(VI) products directed towards the A&D supply chains also varies significantly (from 4% to approximately 100% of the production at individual companies).

3.2 Constraints on substitution by downstream users

3.2.1 Use of the Cr(VI)-containing mixtures

3.2.1.1 Components that may be treated with chromate-based mixtures

All the chromate mixtures used as surface treatments aim to modify the surface of the substrate to improve the substrate properties and adapt it to its specific use conditions. There are many corrosion and wear prone areas on A&D products which require the application of surface treatments. Examples of these are included in Table 3-1 below.

Table 3-1: Examples of corrosion prone areas of A&D products (non-exhaustive)

Structural/flight	Propeller/rotor	Engine/power plant	Additional Space- and Defence-specific
Aileron and flap track area	Blade tulip and hub	Auxiliary Power Units (APUs)	Air-transportable structures
Centre wing box	Gearbox	Carburettor	Fins
Cockpit frames	High bypass fan components	Data recorders	Gun barrels and ancillaries
Differential	Main and tail rotor head assemblies	Engine Booster and Compressors including Fan Containment	Interstage Skirts
Emergency valve landing gear	Propeller speed controller	Engine control unit	Launchers (rocket, satellite, etc.)
Environmental control systems	Propellers	Engine External components	Missile and gun blast control equipment
External fuel tanks	Transmission housing	Fuel pump	Missile launchers
Flight control systems		Gearbox	Pyrotechnic Equipment
Fuselage		Hydraulic intensifier	Radomes
Hydraulic damper		Ram air turbine	Rocket motors
Hydraulic intensifier		Starter	Safe and arm devices
Landing equipment		Vane pump	Sonar
Nacelles			
Pylons			
Rudder and elevator shroud areas			
Transall (lightning tape)			
Undercarriage (main, nose)			
Valve braking circuit			
Window frames			
Wing fold areas			

Source: (GCCA, 2017)

It is important to note that even with the highly developed Cr(VI)-containing treatments available, corrosion and wear of these components still occurs, however decades of experience relating to the appearance and impacts of corrosion on Cr(VI) systems allows the A&D industry to define inspection, maintenance and repair intervals.

Cr(VI)-free alternatives cannot be introduced where they are known to result in a decreased performance in key functions, since some or all of the following consequences may occur:

- Substantial increase in inspections, some of which are very difficult or hazardous to perform;
- Increased overhaul frequency or replacement of life-limited components;
- Possible early retirement of A&D products due to compromised integrity of non-replaceable structural parts;
- Whole fleets may be grounded until a repair/replacement plan is in place for the whole aircraft fleet - This could impact many or all aircraft fleets. Defence systems would be similarly impacted, affecting the continuity of national security;

In addition to the above, there may be limitations set on how far aircraft could fly.

Despite best efforts, hidden properties or incorrect performance predictions of any Cr(VI)-free systems that are ultimately introduced cannot be excluded, and remaining risks must be mitigated. Ultimately extensive qualification and validation testing (as described in section 3.1.2 below) is not equivalent to 50 years real-life experience with corrosion protection.

3.2.1.2 Service life and maintenance intervals of components

Wherever possible, A&D hardware is repaired rather than replaced. In addition to both time and cost considerations, this is a much more environmentally friendly approach from a lifecycle perspective, resulting in reduction of hazardous chemical usage, energy usage, carbon footprint, waste generation, etc. In order to maintain operational safety therefore, A&D components and products are subject to intensive MRO activities.

For aircraft, there are different maintenance activities foreseen after defined intervals of flight hours or take-off or landing cycles:

- Prior to each flight a “walk-around” visual check of the aircraft exterior and engines is completed;
- A-checks entail a detailed check of aircraft and engine interior, services and lubrication of moving systems;
- B-checks involve torque tests as well as internal checks and testing of flight controls;
- In C-checks a detailed inspection and repair programme on aircraft engines and systems is undertaken.
- D-checks include major structural inspections with attention to fatigue damage, corrosion, etc. result in the aircraft being dismantled, repaired and rebuilt.

As an example, for commercial aircraft the A-checks occur every 400-600 flight hours, the B-checks are performed every 6-8 months, and the C-checks are completed every 20-24 months. C-checks typically take up to 6,000 man-hours to complete. The D-checks are completed every 6-10 years and typically take up to 50,000 man-hours to complete. At Lufthansa, the D-check begins with the stripping of the exterior paintwork. The aircraft is taken apart and each /system is checked thoroughly using the most modern methods for non-destructive material testing such as X-rays, eddy current probes and magnetic field checks. After several weeks and thousands of hours of intensive MRO work, the aircraft is overhauled completely. The D-check is the most extensive check foreseen for aircraft. Even at the D-check, certain areas of the aircraft, such as bonded structures and inaccessible regions, cannot typically be disassembled for inspection. Corrosion protection of these regions must therefore be sufficiently robust to last throughout the life of the aircraft.

The aerospace industry has a permanent learning loop of significant events, failure analysis and decisions for safety improvements. Part of this improvement is the introduction of the Maintenance Steering Group 3 Analyse (MSG-3), specifically developed for corrosion. MSG-3 provides a system for OEMs and the regulators to identify the frequency of inspection with respect to the stress corrosion, protection and environmental ratings for any component or system. Without long-term experience the performance of a system cannot be highly rated due to hidden properties which may only be identified when extensive knowledge of in-service behaviour is available. The consequence of this is that the introduction of a Cr-free system would lead to a significant reduction in the maintenance interval, potentially doubling the frequency of the checks described above (GCCA, 2017).

3.2.2 Overview of the substitution process in Aerospace & Defence (A&D)

3.2.2.1 Introduction

Aerospace and Defence (A&D) products operate in highly challenging, extreme environments over extended timeframes. Due to these challenges, alongside engineering-based solutions, the A&D industry must use numerous high-performance mixtures which have passed through an extensive approval process in order to demonstrate their suitability for use – some of these mixtures will contain substances which are included on Annex XIV of REACH. Whilst substitution of substances of very high concern (SVHC) is a priority for the sector, and there have been extensive efforts to eliminate Cr(VI) and other SVHC wherever technically feasible, changes to A&D components offer unique challenges that are not seen in other industries. These include: the industry's dependence on certain SVHC to meet key safety requirements; the level of qualification and regulatory controls associated with introduction of alternative chemicals or other design changes; and the complexity of supply chains and the number of stakeholders involved in the substitution process.

In the civil aviation sector of the Aerospace industry, large numbers of aircraft **safely carry billions of people every year**[10]**,** whilst defence aircraft and systems are required to operate safely and reliably for 40 to more than 90 years before they are finally taken out of service**.** This requires A&D components to successfully fulfil a wide range of extremely challenging safety-related requirements, including but not limited to:

- High utilisation rate (around 16 hours per day for commercial aircraft, whilst critical defence systems must operate continuously for extended periods);
- Environmental and service temperatures ranging from below minus 55°C at cruising altitude to in excess of plus 200°C (Depending on substrate and location on final product);
- Wide ranging and varying humidity and pressure;
- High and varying loads;
- Fatigue resistance under varying modes of stress;

[10] 4.5bn passengers carried and 38.3m departures in 2019. https://www.icao.int/annual-report-2019/Pages/the-world-of-air-transport-in-2019.aspx

- Corrosive and abrasive environments (e.g., salt water and vapour, sand and grit, and exposure to harsh fluids such as cleaning solutions, de-icer, fuels, lubricants, and hydraulic fluids at in-service temperatures); and
- Maintained performance in the possible case of a lightning, bird, or other foreign object strike.

Successful, reliable, and safe performance against these parameters is the result of decades of experience and research, and a high level of confidence in the systems currently employed to provide corrosion and wear resistance. Years of performance data, as well as thorough reviews following any incidents, have resulted in improvements to the designs, manufacturing or maintenance processes employed in the industry. Such a level of confidence in the performance of Cr(VI) is essential as the treatments on some A&D components cannot be inspected, repaired, or replaced during the life of the A&D system. An inadequately performing surface treatment allows corrosion pits to form. These can turn into fatigue cracks, which potentially endanger the final product.

The civil aviation industry must comply with the airworthiness requirements derived from Regulation(EC)No 2018/1139[11] in the European Economic Area (EAA). Similar airworthiness requirements exist in all countries where aeronautical products are sold. These regulations require a systematic and rigorous framework to be in place to qualify all materials and processes to meet stringent safety requirements that are subject to independent certification and approval through the European Aviation Safety Authority (EASA), and other agencies requirements. Safety critical defence aviation and space systems are subject to similar rigorous performance requirements as seen in the civil aviation sector, while ground and sea-based defence systems are managed more adaptively based on specific system requirements.

Identification and implementation of feasible, suitable, and available alternatives in the A&D industry is a time consuming and complex process that can involve multiple stages of performance testing in laboratory trials, manufacturing trials and during inflight/in operation testing. Once a proposed candidate is identified, it must be shown that implementing it will maintain the stringent safety requirements that govern the sector. Not only this but, due to the potential implications of inadequate corrosion and abrasion protection described above, it must be ensured that the test candidate demonstrates equivalence in performance on all types of components where the original formulation/process is used. This can often be hundreds of different components, each requiring testing to ensure performance of the test candidate is acceptable.

The A&D companies that design and integrate the final product (e.g. aircraft, engines, radar, and other defence systems), are each responsible for their own product qualification, validation, and certification, according to airworthiness regulations or defence/space customer requirements. Even superficially similar components, when used in different systems or under different environmental conditions, may have unique design parameters and performance requirements, driven by the requirements of the final product. Consequently, an alternative that has successfully been implemented for one component in a given subsystem will not necessarily be suitable for use in a different subsystem. Implementation of an alternative in varying scenarios of use must be individually assessed, validated, and certified across the components, subsystems and systems that

[11] Repealing Regulation (EC) No 216/2008

make up the final product, for example an engine, aeroplane, helicopter, missile, or tank (as illustrated in **Figure 3-1**).

Defence OEMs have additional challenges because individual defence customers usually assume full design/change authority upon accepting the defence hardware designs. This means that any intent to change the hardware configuration, including coatings and surface treatments, must be approved by the defence agency, who are concerned with the efficacy of the hardware (i.e. mission effectiveness) as well as meeting legislative goals, and can be very fiscally constrained for such hardware configuration updates. Alternatively, an OEM can attempt to persuade their customers of such hardware changes, but typically are not allowed to spend programme budgets on these hardware changes until expressly directed/contracted by the customer, who again are very fiscally constrained. When OEMs sell the same hardware to multiple defence customers, it is often required to obtain permission from each customer prior to hardware changes and these customers rarely agree. The combination of (a) not mission essential, (b) fiscal constraints, and (c) multiple conflicting customer opinions, greatly complicates any defence OEM effort to make hardware changes to existing designs to meet legislated goals such as chrome elimination.

The processes described apply to the implementation of any new design, or changes to an existing design whether still in production or not. This means, to ensure and maintain airworthiness and operational safety standards, they apply to every component produced for use in an aircraft or defence system. In the case of introducing Cr(VI)-free surface treatments, hundreds of individual components in each final product will be affected.

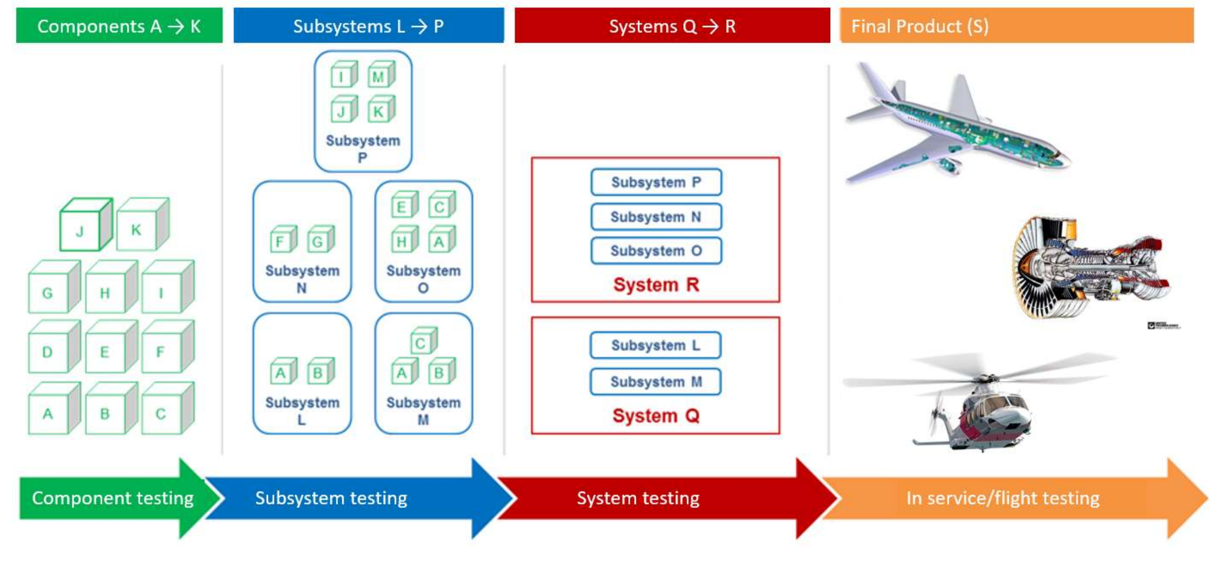

Figure 3-1: Assessment requirements in the implementation of alternatives
Source: Adapted from GCCA white paper

In the substitution process, many ADCR Consortium members use the Technology Readiness Level (TRL) scale as developed by the US National Aeronautics and Space Administration (NASA), and further defined by the US Department of Defence. This scale is used to assess the maturity level of each individual technology, and hence the potential suitability of a test candidate. The scale ranges from TRL 1, basic principles observed, to TRL 9, actual system proven.

Table 3-2: Technology Readiness Levels as defined by US Department of Defence		
TRL	**Definition**	**Description**
1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.
2	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	Analytical and experimental critical function and/or characteristic proof-of-concept	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	Component and/or breadboard[a] validation in laboratory environment	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5	Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.
6	System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7	System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space).
8	Actual system completed and qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.
9	Actual system through successful mission[b] operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.

[a] Breadboard: integrated components, typically configured for laboratory use, that provide a representation of a system/subsystem. Used to determine concept feasibility and to develop technical data.
[b] Mission: the role that an aircraft (or system) is designed to play.
Source: U.S. Department of Defence, April 2011, https://www.ncbi.nlm.nih.gov/books/NBK201356/

The TRL assessment guides engineers and management in deciding when a test candidate (be it a material or process) is ready to advance to the next level. Early in the substitution process, technical experts establish basic criteria and deliverables required to proceed from one level to the next. As the technology matures, additional stakeholders become involved, and the criteria are refined based on the relevant design parameters. A formal gate review process has been established by some companies to control passage between certain levels in the process.

Similarly, the maturity of manufacturing processes is formally tracked using the Manufacturing Readiness Levels (MRL) process. MRLs are used to assess the maturity of a given component, subsystem, or system from a manufacturing process.

Table 3-3: Manufacturing Readiness Levels as defined by US Department of Defence

MRL	Definition	Description
1	Basic Manufacturing Implications Identified	Basic research expands scientific principles that may have manufacturing implications. The focus is on a high-level assessment of manufacturing opportunities. The research is unfettered.
2	Manufacturing Concepts Identified	This level is characterized by describing the application of new manufacturing concepts. Applied research translates basic research into solutions for broadly defined military needs.
3	Manufacturing Proof of Concept Developed	This level begins the validation of the manufacturing concepts through analytical or laboratory experiments. Experimental hardware models have been developed in a laboratory environment that may possess limited functionality.
4	Capability to produce the technology in a laboratory environment	This level of readiness acts as an exit criterion for the MSA Phase approaching a Milestone A decision. Technologies should have matured to at least TRL 4. This level indicates that the technologies are ready for the Technology Development Phase of acquisition. Producibility assessments of design concepts have been completed. Key design performance parameters have been identified as well as any special tooling, facilities, material handling and skills required.
5	Capability to produce prototype components in a production relevant environment	Mfg. strategy refined and integrated with Risk Management Plan. Identification of enabling/critical technologies and components is complete. Prototype materials, tooling, and test equipment, as well as personnel skills have been demonstrated on components in a production-relevant environment, but many manufacturing processes and procedures are still in development.
6	Capability to produce a prototype system or subsystem in a production relevant environment	This MRL is associated with readiness for a Milestone B decision to initiate an acquisition program by entering into the EMD Phase of acquisition. Technologies should have matured to at least TRL 6. The majority of manufacturing processes have been defined and characterized, but there are still significant engineering and/or design changes in the system itself.
7	Capability to produce systems, subsystems, or components in a production representative environment	System detailed design activity is nearing completion. Material specifications have been approved and materials are available to meet the planned pilot line build schedule. Manufacturing processes and procedures have been demonstrated in a production representative environment. Detailed producibility trade studies are completed and producibility enhancements and risk assessments are underway. Technologies should be on a path to achieve TRL 7.
8	Pilot line capability demonstrated; Ready to begin Low Rate Initial Production	The system, component or item has been previously produced, is in production, or has successfully achieved low rate initial production. Technologies should have matured to TRL 9. This level of readiness is normally associated with readiness for entry into Full Rate Production (FRP). All systems engineering/design requirements should have been met such that there are minimal system changes. Major system design features are stable and have been proven in test and evaluation.
9	Low rate production demonstrated; Capability in place to begin Full Rate Production	The system, component, or item has been previously produced, is in production, or has successfully achieved low-rate initial production (LRIP). Technologies should have matured to TRL 9. This level of readiness is normally associated with readiness for entry into Full-Rate Production (FRP). All systems engineering/design requirements should

Table 3-3: Manufacturing Readiness Levels as defined by US Department of Defence		
MRL	**Definition**	**Description**
		have been met such that there are minimal system changes.
10	Full Rate Production demonstrated and lean production practices in place	Technologies should have matured to TRL 9. This level of manufacturing is normally associated with the Production or Sustainment phases of the acquisition life cycle. Engineering/design changes are few and generally limited to quality and cost improvements. System, components or items are in full-rate production and meet all engineering, performance, quality and reliability requirements. Manufacturing process capability is at the appropriate quality level.
Source: Manufacturing Readiness Level (MRL) - AcqNotes		

Many companies combine the TRLs and MRLs in their maturity assessment criteria, as issues in either the technology or manufacturing development could affect production readiness and implementation of an alternative material/process. It should be noted that not all affected components in a system will necessarily attain the same TRL or MRL at the same time.

The process described above places limitations on the ability of the design owner, such as an original equipment manufacturer (OEM), to use "generic" commercially qualified components or "generic" commercially qualified formulations without extensive in-house testing. In general, such a component or formulation is unlikely to have been tested in a suitably qualified laboratory. The testing would need to cover all the design owner's specific configurations, involving all relevant substrates, and to consider interactions with all relevant chemicals including, but not limited to, paints, solvents, degreasers, de-icers, hydraulic fluids, and oils. There will also be specific testing required by a design owner in specific configurations which the producer of the component or formulator is not able to test.

The following section summarises the multi-step, multi-party processes that must be completed to develop test candidates and implement a Cr(VI)-free alternative into the supply chain, whilst highlighting the anticipated time necessary to complete these highly regulated processes. It should be noted that many ADCR members have multiple projects with the aim of developing and industrialising Cr(VI)-free alternatives running in parallel, as hexavalent chromates are used in a number of steps in surface treatment processes. Whilst the proposed candidates will be different for each use, taking into account the different requirements of the existing materials, the highly specialised individual experts at both formulator and design owner, and the required testing facilities, will be common. The competing priorities, and the capacity and specialised resource constraints, created by the need to substitute multiple chromates to the same timeframe will therefore also have a negative impact on the timeframes usually associated with the substitution process.

3.2.2.2 Process, requirements and timeframe

Identification & Assessment of need for substitution

When a substance currently used in the production of A&D components is targeted for regulatory action and needs to be replaced, a component design change may be triggered. Completely removing a substance from one component may impact upon multiple other components and systems, and involve many different processes with varying performance requirements.

The first step is to identify extent to which the substance, or the formulation containing the substance, is used. This must consider the entire life cycle of components containing the substance throughout the supply chain, including maintenance, repair, and overhaul (MRO) activities. After identifying the relevant formulations, processes, and design references, the affected component designs and related systems are identified. This is the first step to assess the impact of substituting the substance and the scale of the design changes which may be needed.

The above work requires contributions from numerous personnel from various departments including Materials & Processes, Research & Development, Design & Definition, Engineering, Customer Service, Procurement, Manufacturing, Supply Chain, and Certification. Assembling this multi-disciplinary team and co-ordinating their activity is itself a complex and time-consuming activity.

Components on which Cr(VI)-based surface treatments are currently used may have been designed 30 to 40 years ago (or more), using design methods and tools that are no longer in use. Attempting to determine the potential interactions/incompatibilities of a Cr(VI)-free formulation or surface treatment process in an old design can take a tremendous amount of work. Failing to adequately identify all interactions creates a significant risk, whilst resolving any incompatibilities between old and new treatment materials and/or techniques is time intensive and has a high chance of failure.

When an existing design specifies a formulation or process utilising Cr(VI), the design change must not only comply with the performance requirements of the newly introduced components, but also be compatible and seamlessly interact with remaining legacy designs. This is because maintenance may require a Cr(VI)-free alternative to be applied proximal to the legacy formulation, containing Cr(VI). If the re-design is going to be integrated with old components treated with Cr(VI), compatibility must be assured.

Definition of requirements

Once a project seeking to develop and industrialise an alternative is launched, materials and process specialists from engineering, manufacturing, procurement, and MRO departments at the design owner, define the requirements that the proposed candidate must fulfil in order to be a suitable test candidate.

Alternatives must satisfy numerous requirements. In many cases those identified introduce competing technical constraints and lead to complex test programmes. This can limit the evaluation of proposed candidates. Categories of technical requirements may include:

- Performance requirements (e.g., corrosion resistance, wear resistance, adhesion strength, and compatibility with other materials);
- Design requirements (e.g., compatibility of the component's geometric complexity with the coating technique);
- Industrial requirements (e.g., robustness, processability, and repeatability); and
- Environment, Health & Safety (EHS) requirements (e.g., is there an equivalent level of concern).

For some materials dozens of individual requirements may exist across these categories.

Definition of requirements itself can be complex and requires a significant timeframe. The complexity can be due to:

- The substitute exhibiting behaviours or interactions which are different to the original product. Where unexpected behaviour is seen, sufficient operational feedback to technically understand the phenomenon and refine the requirements is essential to ensure non-regression;
- Consolidating requirements from multiple customers and suppliers into an existing design;
- Evolution of EHS regulations; and
- Need to substitute multiple chromates to the same timeframe.

Development of initial requirements can take at least six months, although requirements may be added and continue to be refined during the different levels of maturity, based on learnings from the various testing/qualification stages.

Key phases of the substitution process

Once initial technical requirements are defined, test candidates can then be identified and tested by the design owner. **Figure 3-2**, revised from the Global Chromates Consortium for Aerospace (GCCA) Authorisation applications, shows a schematic of the various stages in the process, which are described further below. These steps are not simply performed one after the other or presented in a chronological order, but rather they represent an iterative process.

Each stage in the process comprises various steps including extensive laboratory testing programmes and, in some situations, in service/flight testing. Each step therefore requires flexibility in the time to be completed, typically taking years overall. It should be noted that there can be **failures at any stage in this process**, and failures may not reveal themselves until a large amount of testing, taking considerable time and incurring significant expense, has already been carried out. Such failures result in the need to return to earlier steps in the process and repeat the extensive testing and associated activities leading to industrialisation. The later in the process these failures occur, the greater the impact will be on schedule and cost.

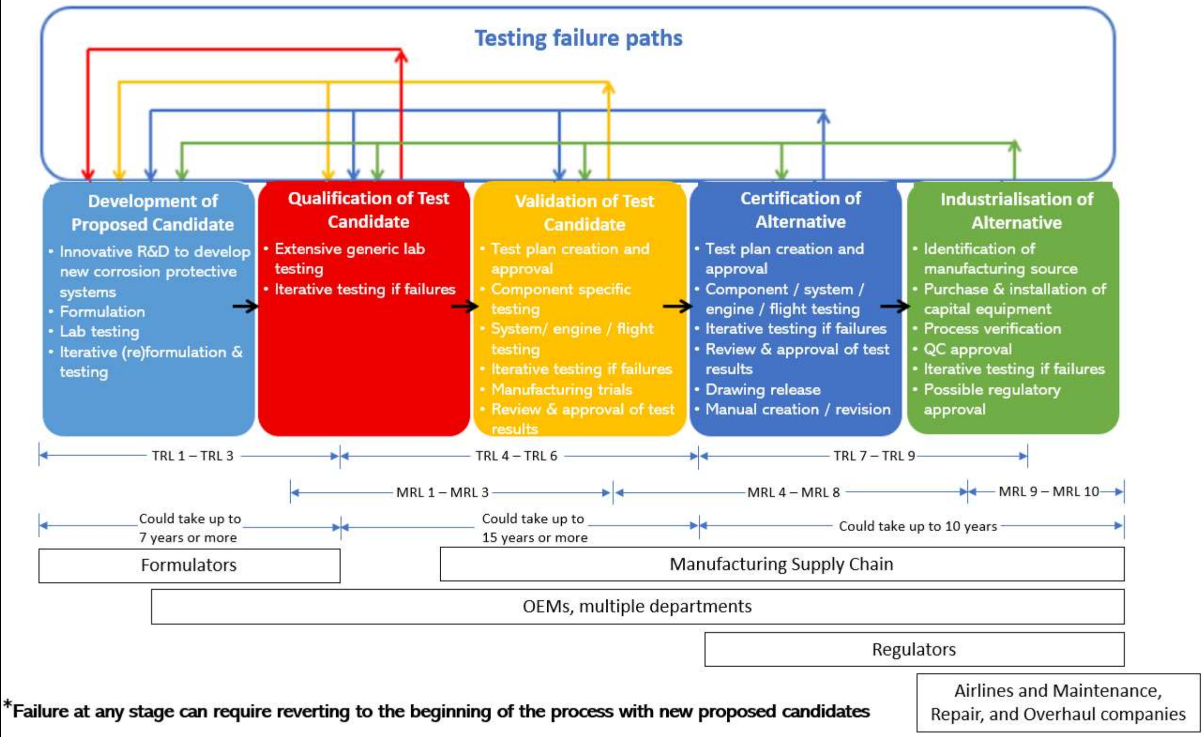

Figure 3-2: Schematic showing the key phases of the substitution process
Typical TRLs and MRLs associated with each stage, and the entities involved in each stage, are also shown. Note that failure of a proposed candidate at any stage can result in a return to a preceding stage including TRL 1. Note that failures may not become apparent until a late stage in the process.
Source: Adapted from "Use of strontium chromate in primers applied by aerospace and defence companies and their associated supply chains, Application for Authorisation 0117-01, GCCA (2017)

The detailed process involved in each phase of the substitution process is described below, and the associated timeframes are elaborated. Throughout the process it should be remembered that the initial qualification, validation, and certification of a final product is applicable to a single specific configuration of components and materials, assembled by a single set of manufacturing processes. Any change to the components, materials, or manufacturing processes invalidates this initial qualification and certification. The action to approve and industrialise the change can only proceed once a suitable test candidate is developed, qualified, and validated.

Development of proposed candidates

When a need to develop an alternative has been identified (for example, as in this case, because of regulatory action driving the need to make an informed substitution), the first stage comprises innovative R&D, most commonly by the formulator(s), to develop new formulations. Initial activities in the development of proposed candidates stage include:

- Innovative R&D to develop new surface treatments;
- Formulation of proposed candidates;
- Laboratory testing of proposed candidates; and
- Iterative re-formulation and testing.

The development of proposed candidates must take into consideration the complex design parameters identified in the requirements development step discussed above. Once a proposed candidate is developed, testing is carried out in the formulator's laboratory to assess quantitative performance of the new formulation against the critical criteria required by the design owner. Failure against any of these criteria may result in rejection of the proposed candidate, further modification of the formulation, or additional testing. Although it may only be the Cr(VI) compound within a mixture which is subject to regulatory action, the other constituents may also require substantial change to continue to meet the stated performance requirements.

Formulators perform screening tests on small test pieces of substrate. Such tests provide an indication of whether basic performance criteria have been met, in order to justify more extensive testing by the design owner. The predictive power of laboratory tests performed by the formulators is limited and therefore it is vital to note that a formulation that passes these screening tests is not necessarily one that will be technically suitable to ultimately be fully implemented in the supply chain. **Passing these initial tests is a *necessary, but not sufficient***, pre-requisite for further progression through the process (i.e. a building blocks approach is followed).

Development typically involves an iterative process of re-formulation and re-testing to identify one or more proposed candidate. It is important to note that many iterations of these formulas are rejected in the formulator's laboratory and do not proceed to evaluation by the design owner. Formulators estimate that it typically takes two to five years of testing potential formulations before a proposed candidate is identified for submittal to the design owner[12].

Qualification of test candidate

Qualification is the first step in the process under which a design owner begins to verify that the treatment which may ultimately replace the Cr(VI)-based surface treatment has met or exceeded the specific performance criteria defined at the beginning of the substitution process.

Qualification applies to materials, manufacturing processes, and components, and comprises:

- Extensive generic laboratory testing; and
- Iterative testing if failures occur.

Once proposed candidates are developed by the formulator, the design owner evaluates the formulations by first performing their own screening tests. If the test candidate fails, formulators may choose to reformulate. It is common to iterate multiple times before a test candidate passes the design owners' screening, potentially adding several years to the substitution process (see **Figure 3-2** above).

For those test candidates which pass initial screening, additional testing is performed. Each company has explicit performance requirements, test methods, acceptance testing, and other characteristics for each component that are based upon the results of research, development, and prior product experience. This phase of the substitution process can take multiple years depending

[12] GCCA

upon the performance requirements and only successfully qualified test candidates can progress to the validation stage described below.

Validation of test candidate

After a test candidate is qualified, the performance of each particular aerospace or defence use is validated based on its specific design criteria.

Validation is carried out on each relevant component, followed by system-level testing and engine/flight testing (if relevant). The activities in this stage can overlap with some of those that are carried out in the Certification stage and include:

- Test plan creation and approval;
- Component specific testing;
- Iterative testing if failures occur;
- System/engine/flight testing;
- Manufacturing trials; and
- Review and approval of test results.

The testing criteria are determined on a case-by-case basis with due regard to the design and performance requirements of each component and system. Testing in a relevant environment over an appropriate timescale is necessary, and therefore the validation stage may require full engine and aircraft flight tests, even for very low volumes of product. In the validation of manufacturing processes, the process robustness is also a vital aspect to be demonstrated at this stage.

Validation is carried out by the aerospace and defence companies, sometimes in collaboration with the manufacturing supply chain (in the Certification stage, the Regulator is also involved). Only the original design owner can determine when a test candidate is fully validated.

Some of the components impacted by the substitution of a surface treatment may form part of systems which are no longer in production. In order to conduct the testing required to validate the change on these components, it may therefore be necessary to build bespoke test hardware. Sourcing the relevant hardware and test equipment, and finding test facilities to do this, can add significant time to the process, whilst some of the testing performed at this stage will also be destructive, so failures can result in further schedule slippage. Together the Qualification and Validation processes encompass testing of the test candidate and can take more than 15 years to complete for the most challenging substitutions. At the end of the validation stage the removal of Cr(VI) from the production process is formally approved by the design owner.

Certification of alternative

Certification is the stage under which the component onto which the test candidate will be applied is certified by the Regulator or relevant authority as compliant with safety, performance, environmental (noise and emission) and other identified requirements. OEM's work with the certification authorities to develop a comprehensive plan to demonstrate that the aircraft, engine, propeller, radar system, munitions or any other final product complies with the airworthiness regulation or defence/space customer requirements. This activity begins during the initial design phase and addresses the final product in normal and specific failure conditions. The airworthiness regulations set performance criteria to be met, although they do not specify materials or substances to be used.

Steps in the Certification stage include:

- Test plan creation and approval;
- Component/system/engine/flight testing;
- Iterative testing if failures occur;
- Review and approval of test results;
- Drawing release; and
- Maintenance manual creation/revision.

For the civil aviation industry, the output of the original certification process is a Type Certificate, issued by the airworthiness authority (e.g. EASA) and granted to the engine, propeller, and airframe OEM. This is issued for the original design of the final product, rather than for each individual component, however every component of the final product must be designed, developed, and validated as meeting the requirements of the overall product and system design. The overall compliance demonstration for a new Type Certificate therefore may cover several thousand individual test plans, of which some will require several years to complete. This interconnection is illustrated using the example of an aircraft in **Figure 3-3** below.

Certification therefore applies to all components, sub-systems, and systems. A change to one individual component can affect the entire assembly of which it is a part (which may contain hundreds of components), and in turn the sub-system and system. Approval of the impacted components is granted after the airworthiness certification criteria, compliance standards/requirements and methods of compliance have been successfully demonstrated for those components, to the relevant Airworthiness Authority. The same process applies to defence products and systems, with the only distinction being how acceptable means of compliance are defined, and the certification authority (which will usually be a Ministry of Defence (MoD)). In the case of dual use aircraft (A civil and a military version of the same aircraft), or in the case of military specific aircraft, certification may need to be granted by multiple authorities (e.g. certification by the MoD could apply in addition to the EASA certification).

Removing a material or process reliant upon Cr(VI) and implementing an alternative is particularly challenging as it will involve in service or in production components. Re-certification of all components incorporating the new processes and materials is therefore required. As discussed in the description of the certification process in the GCCA AfA for strontium chromate[13], each of these components will need to be approved individually:

> *"Importantly, even if an alternative is in use in one component in aerospace[14] system A, it cannot be inserted into what appears to be the same part [component] in another aerospace system B (e.g., model B) until it is fully reviewed/validated/certified to ensure that either the*

[13] Application for Authorisation 0117-01 section 5.3 available at b61428e5-e0d2-93e7-6740-2600bb3429a3 (europa.eu) accessed 06 June 2022

[14] In this parent dossier, the term aerospace is defined as comprising the civil aviation, defence/security and space industries.

design parameters are identical or that the alternative is fully acceptable for the different design parameters. Extensive experience shows that an alternative that is successfully certified in one component in one model cannot necessarily be successfully certified in another. In other words, the circumstances for each component in each model are unique and extrapolation is impossible without validation and certification.”

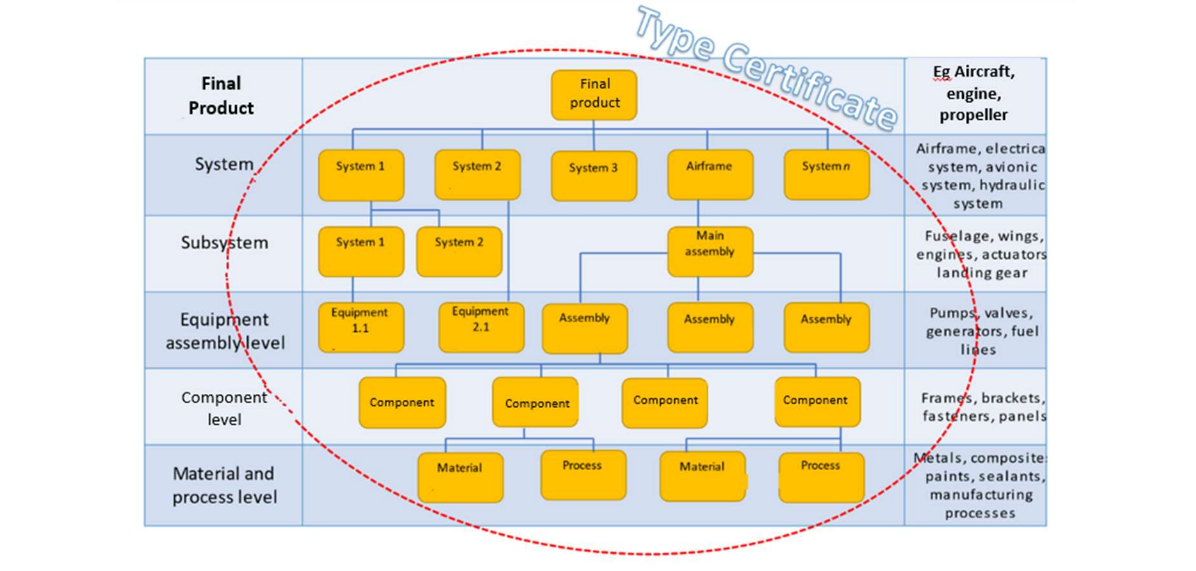

Figure 3-3: System hierarchy of a final product, showing the interconnection of each level in the system hierarchy, and how changes at a lower level have impacts on higher levels
Source: ADCR Member

After the alternative is certified, design drawings and part lists need to be revised to put the requirements of the Cr(VI)-free material/process as an alternative to the legacy requirements. Thousands of components could be impacted by each process. Only once these revised design drawings have been released can industrialisation of the alternative begin.

Over their operational life A&D components are exposed to extreme mechanical forces and environmental conditions which affect their performance. In order to continue to meet requirements, and ensure operational safety, A&D components and products are therefore subject to intensive MRO activities. The strict schedule of the maintenance program, and method for repair, is stated in the maintenance manual and must be officially approved. For most A&D organisations, repair approval is distinct from design approval, although the processes are analogous and may be undertaken concurrently. Once repair approval is complete the alternative will be included in maintenance manuals.

During initial manufacture, all the components of the system are in a pristine and relatively clean condition, whereas during repair and maintenance, the components are likely to be contaminated and suffering from some degree of (acceptable) degradation. Furthermore, certain cleaning and surface preparation techniques that are readily applicable during initial manufacture may not be available or practical during repair and maintenance. Carrying out MRO activities on in-service products is further complicated due to restricted access to some components, which are much more readily accessible during initial manufacture and assembly. These factors are significant with respect to surface treatments, as their performance is strongly dependent upon the condition of the surfaces to which they are applied. As such, all these conditions must be addressed in the repair approval process.

The certification and industrialisation stages (see below) encompass progression of the alternative from TRL 7 to TRL 9 and together these stages can take six to ten years to complete. In certain defence applications, certification alone can take more than ten years.

Industrialisation of alternative

Industrialisation follows the certification of the component design incorporating the alternative and is an extensive step-by-step methodology followed to implement the certified material or process throughout manufacturing, supply chain and MRO operations, leading to the manufacturing certification of the final product.

Elements of the Industrialisation of alternative process include:

- Identification of potential manufacturing sources;
- Purchase and installation of manufacturing equipment;
- Process verification (Due to the fact that the industry is working on special processes, the supply chain must be qualified);
- Quality Control (QC) approval; and
- Regulatory approval if needed.

A&D products consist of up to a million components provided by thousands of suppliers or manufactured internally by OEMs, making communication between OEMs and their supply chain regarding what is permissible for use on A&D products key. Suppliers must be vetted through a supplier qualification process prior to being issued a contract. This process typically involves internal approval, contract negotiation, running a specific qualification test program, and undertaking an audit on potential risks of working with a supplier. A supplier may be requested to sign a manual or code of conduct by the OEM, to ensure expectations for work and awareness of required standards is achieved. Once the supplier is qualified, periodic audits are performed to ensure continued compliance with contractual requirements. Significant investment, worker training and manufacturing documentation may be required to adapt the manufacturing processes for new alternatives, which sometimes require changes in existing facilities, the construction of new facilities, or switching to a different facility (including a different supplier's facility).

The industrial implementation is usually scheduled to follow a stepwise approach to minimise the technical risks, and benefit from lessons learned. This implies that the replacement is not implemented simultaneously in all plants and at all suppliers but instead often uses a stepwise approach. Each OEM may operate dozens of manufacturing sites/final assembly lines worldwide.

For components already in products, long-term contractual agreements are often already in place with suppliers. When a change is made to a drawing to incorporate a new alternative, the contract with the supplier needs to be renegotiated, and additional costs are incurred by the supplier when modifying and/or introducing a new production process. These may include purchase and installation of new equipment, training of staff, internal qualification of the new process, OEM qualification of the supplier, manufacturing certification of the supplier, etc. In addition, the supplier may need to retain the ability to use the old surface treatment, or qualify different solutions for different customers/components, which requires the supplier maintain parallel process lines to accommodate multiple surface treatments/processes. The level of complexity varies by component and process. In some cases, the supplier may be sub-contracting the process. In addition to production organisation approval, the approval of maintenance organisations is also required. This means multiple layers of activity in the industrialisation process.

The industrialisation of alternatives is constrained by many factors including: the complexity of supply chains; extent of process changes required; and the airworthiness regulations or defence/space customer requirements. Even simple changes can take up to five years. When more than one alternative process is introduced simultaneously, up to a decade or more may be necessary for full implementation of the alternative.

The industrialisation process includes the creation and approval of process documents or manufacturing/repair documents. These documents allow detailed implementation of the manufacture and/or repair of each component.

Using the example of a commercial aircraft, a simplified example of the process, described above and leading to industrialisation of the alternative, is illustrated in below.

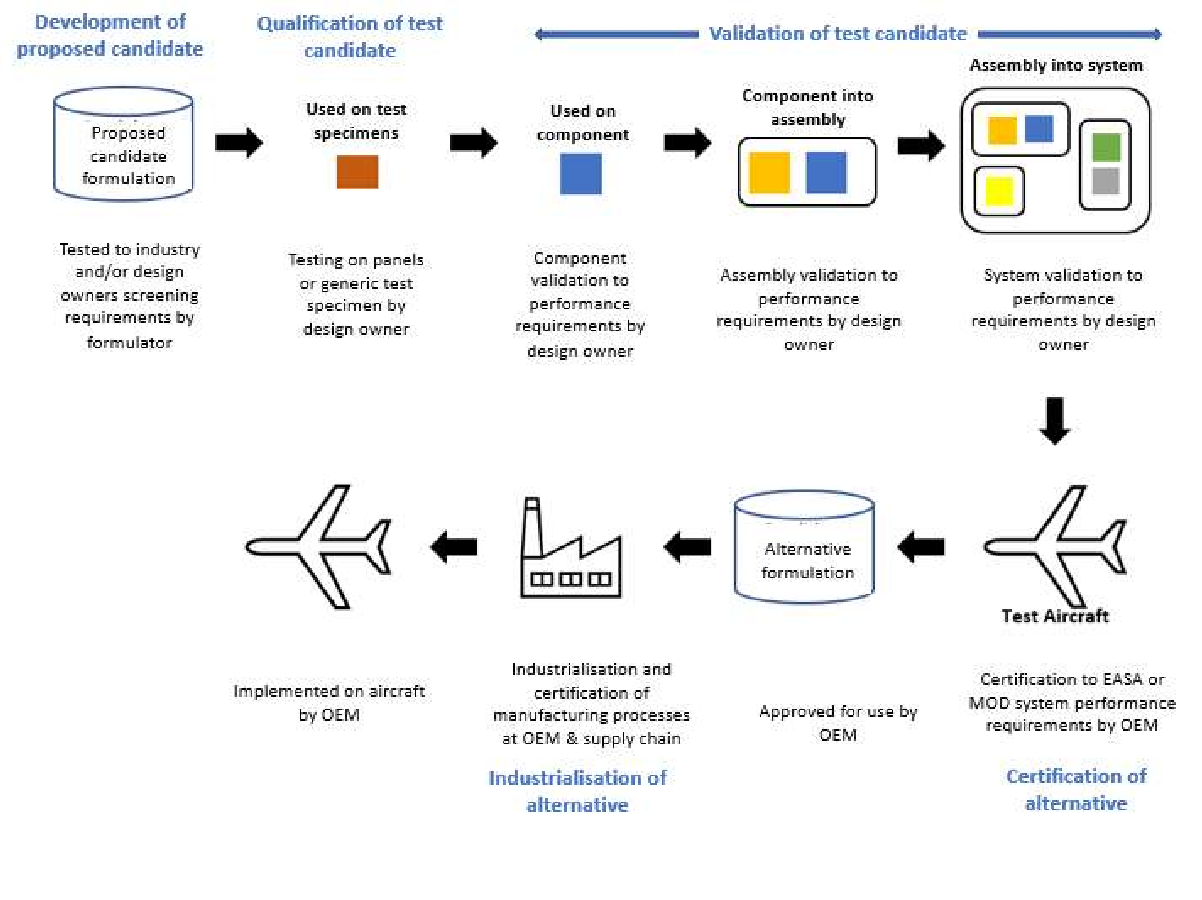

Figure 3-4: Process to Certify a Formulation for use on Aircraft
Formulations used in production have completed this process. New or reformulations must follow same process for use in production.
Source: ADCR Member

4 Continued Use Scenario

4.1 Introduction

Cr(VI)-based mixtures have been used in the A&D sector for decades in order to meet corrosion protection and other functional requirements. Although research and development activities have been carried out with the aim of finding substitutes for the last 30 plus years, alternatives are still in the development and testing phase for use in the manufacture, maintenance and repair of some A&D products.

These research activities are carried out jointly by the A&D companies and the formulators of mixtures for the sector.

4.2 Market analysis

4.2.1 Global Exports of the chromates

The four chromates used in formulation activities in the EEA and UK (two of the four) are imported into the EU from South Africa, Turkey, Kazakhstan. Other imports occur from India and China, and in previous years from Russia.

The World Bank provides global data on trade and tariffs through the World Integrated Trade Solution (WITS) platform (https://wits.worldbank.org/about_wits.html). Data on imports/exports are available on various chromates identified by the six-digit HS Customs Code (note that there are no separate data for potassium dichromate (284140)):

- 281910 chromium trioxide
- 281430 sodium dichromate
- 284150 other chromates

Global export data (expressed as tonnes per year – t/yr) for the key countries are provided below in **Table 4-1**, with the main chromate exporters being located in the countries where the chromates originate. The associated values of these exports are presented in **Table 4-2**. The reference year has been taken as 2019 to mitigate distortions in data due to Covid-19 in 2020 and 2021.

Table 4-1: Global exports of chromates by exporting country - tonnes per year (2019)

Exporting Country	Chromium Trioxide [1]	Sodium Dichromate [2]	Other Chromates [3]	Total (t/yr)
South Africa	4,775	35,696	4	40,475
Kazakhstan	12,345	10,362	698	23,405
Turkey [4]	17,154	0	0	17,154
Russian Federation	2,961	11,822	1,026	15,808
India	1,738	431	895	3,064
China	2,046	818	171	3,035

Sources:
1) Chromium Trioxide exports (2019), available from:

Table 4-1: Global exports of chromates by exporting country - tonnes per year (2019)
https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Exports/partner/WLD/product/281910 2) Sodium Dichromate exports (2019), available from: https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Exports/partner/WLD/product/284130 3) Chromates, dichromates, peroxochromates; n.e.s. in heading no. 2841 exports (2019), available from: https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Exports/partner/WLD/product/284150 4) Turkey only exports Chromium Trioxide but most recent WITS data are from 2016: https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2016/tradeflow/Exports/partner/WLD/product/281910

Table 4-2: Global exports of chromates by exporting country and value (2019)

Exporting Country	Chromium Trioxide [1]	Sodium Dichromate [2]	Other Chromates [3]	Total
	Units (x €1,000)			*€m*
South Africa	€ 10,883	€ 39,397	€ 7	€ 50,287
Kazakhstan	€ 21,419	€ 9,617	€ 1,227	€ 32,263
Turkey [4]	€ 41,778	€ 0	€ 0	€ 41,778
Russian Federation	€ 6,584	€ 13,776	€ 8,307	€ 28,666
India	€ 4,656	€ 524	€ 2,282	€ 7,462
China	€ 4,621	€ 923	€ 608	€ 6,152

Sources:
1) Chromium Trioxide exports (2019), available from:
https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Exports/partner/WLD/product/281910

2) Sodium Dichromate exports (2019), available from:
https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Exports/partner/WLD/product/284130

3) Chromates, dichromates, peroxochromates; n.e.s. in heading no. 2841 exports (2019), available from:
https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Exports/partner/WLD/product/284150

4) Turkey only exports Chromium Trioxide but most recent WITS data are from 2016:
https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2016/tradeflow/Exports/partner/WLD/product/281910

4.2.2 Imports of the chromates into the EEA and UK

4.2.2.1 EEA imports

The EEA accounts for a significant share of global consumption, based on the above export data. Data on imports into EEA countries in 2019 are provided below in **Table 4-3**. The associated values of these exports are presented in **Table 4-4**.

Table 4-3: 10 largest EU importers of chromates in 2019 (ranked by tonnage)				
Importing Country	**Chromium Trioxide [1]**	**Sodium Dichromate [2]**	**Other Chromates [3]**	**Total (t/yr)**
Germany	8,467	23,704	58	32,229
Estonia	9,452	10,290	703	20,445
Italy	2,158	4,455	4	6,617
Romania	684	3,091	1	3,777
France	1,373	1,235	922	3,530
Austria	102	2,461	4	2,567
Poland	645	1,101	2	1,748
Spain	854	417	3	1,274
Czech Republic	361	3	3	368
Belgium	64	163	23	250

Sources:
1) Chromium Trioxide imports (2019), available from: https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Imports/partner/WLD/product/281910#

2) Sodium Dichromate imports (2019), available from: https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Ixports/partner/WLD/product/284130

3) Chromates, dichromates, peroxochromates; n.e.s. in heading no. 2841 imports (2019), available from: https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Imports/partner/WLD/product/284150#

Entries in shaded cells are estimated based on the $ value of the imports.

Table 4-4: Values of Major EU Imports of Chromates in 2019 (x €1,000)				
Importing Country	**Chromium Trioxide [1]**	**Sodium Dichromate [2]**	**Other Chromates [3]**	**Total Value**
	Units (x €1,000)			*€m*
Germany	€ 19,774	€ 33,755	€ 330	€ 53.9
Estonia	€ 16,192	€ 9,543	€ 1,235	€ 27.0
Italy	€ 5,347	€ 6,343	€ 48	€ 11.7
Romania	€ 1,859	€ 3,962	€ 25	€ 5.8
France	€ 3,544	€ 2,306	€ 2,123	€ 8.0
Austria	€ 262	€ 3,114	€ 22	€ 3.4
Poland	€ 1,646	€ 1,183	€ 26	€ 2.9
Spain	€ 2,277	€ 600	€ 43	€ 2.9
Czech Republic	€ 941	€ 39	€ 39	€ 1.0
Netherlands	€ 187	€ 241	€ 110	€ 0.5

Sources: As previous table

The main EEA importers are the gateways for exports into the EEA from, primarily, South Africa, Kazakhstan, Turkey and previously the Russian Federation. As such, totalling the figures for all EEA imports is misleading as chromates can be imported into the EEA, re-exported to another EEA country (thus appearing as another export and import), then formulated into a product and/or distributed to another EEA country (thus appearing as another export and import).

Although WITS does provide figures for imports into the EEA as whole, the figures seem on the low side, particularly for chromium trioxide. Overall, it is estimated that the EEA imports around 10-15,000 t/yr of Chromium Trioxide, around 35-42,000 t/yr of Sodium Dichromate and up to 2,000 t/yr of other chromates of interest.

Table 4-5: Total EU import of chromates (tonnes per year)	
Substance	**EU Imports in 2019 (t/yr)**
Chromium Trioxide	10,261
Sodium Dichromate	40,900
Other chromates	1695
Total tonnes	**52,856**
Sources: As previous table	

4.2.2.2 UK Imports

Data for UK imports also based on WITS are provided in **Table 4-6** below.

Table 4-6: UK imports of chromates (tonnes per year)		
Substance	**UK Imports in 2019 (t/yr)**	
	t/year	**Value (£m)**
Chromium Trioxide	1,112	£2.4
Sodium Dichromate	724 (estimated)	£0.9
Other chromates	831	£1.6
Total	**2,667**	**£4.9**

Sources:
1) Chromium Trioxide imports (2019), available from: https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Imports/partner/WLD/product/281910#

2) Sodium Dichromate imports (2020), available from: https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2020/tradeflow/Ixports/partner/WLD/product/284130

3) Chromates, dichromates, peroxochromates; n.e.s. in heading no. 2841 imports (2019), available from: https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Imports/partner/WLD/product/284150#

4.2.3 Quantities of Cr(VI) used in formulation

Consultation with formulators was carried out to gather the information necessary for the CSR and for the SEA. Based on the information collected from them, estimates of the maximum tonnages of each of the chromates that may be used in formulation of A&D products have been derived. These are provided below. It should be noted that these figures represent upper bounds of the aggregate amounts and have been developed to protect commercially sensitive data.

The quantities and percentage of total imports used in the A&D formulation activities supported by the ADCR are given in **Table 4-7**.

Table 4-7: Quantities of chromates used per year in formulation activities - tonnes per year (2021)		
	Tonnes per year used in formulation (t/y)	**% of total imports 2019/20**
Chromium trioxide	600	5.85%
Sodium dichromate	100	0.29%
Potassium dichromate	42	2.54%[1]
Sodium chromate	1.1	

Notes:
1. This percentage is illustrative only given that more than just potassium dichromate and sodium chromate will fall under this WITS entry.

As can be seen from **Table 4-7** only a small percentage of the chromates imported into the EU are used in formulation of mixtures for use by the A&D sector in both the EEA and UK.

Furthermore, these figures reflect levels of demand for the Cr(VI) mixtures in 2021 and will therefore represent an overestimate of the quantities used in formulation activities over the requested 12 year review period, as substitution progresses across the surface treatments in which they are used.

4.3 The continued use scenario

4.3.1 The continued use scenario for the formulators

The mixtures used by the A&D industry contain varying concentrations weight/weight of the chromates. In order to calculate an illustrative market value for these mixtures, data were collected through internet searches and combined with data on the concentration of the chromates in end mixtures following formulation. The prices of formulations were gathered from leading specialist distributors of chemical consumables used throughout the aerospace and defence industry. Concentrations of the chromates in the mixtures are based on the "products" being supported across all ten surface treatment review reports prepared by the ADCR.

The results of this analysis are provided in **Table 4-8**, based on average prices for mixtures placed on the market and an assumed 10% profit margin (typical of the chemicals industry). Although use of average prices for the most common mixtures placed on the market will underestimate the economic value across all formulation activities, it protects the commercial interests of the formulators covered by this combined SEA-AoA. Protecting such information is considered appropriate in this case, as justification for the continued use of the chromates in formulation is based on the critical role that the mixtures play in downstream activities rather than in generating profits for the formulators.

Table 4-8: Illustrative profit estimates for the sale of Cr(VI) based mixtures in the EEA and UK combined

	Max concentration w/w	Tonnes Chromate	Kgs / litres of product	Average price for formulation placed on the market per kg/litre	Market value	Profit at typical 10%
Chromic acid solution	50%	600	1,200,000	€ 20.00	€ 25,200,000	€ 2,520,000
Sodium dichromate aqueous solution	70%	100	142,857	€ 50.00	€ 7,143,000	€ 714,300
Potassium dichromate solution	35%	42	120,000	€ 60.00	€ 7,200,000	€ 720,000
				Totals	€ 39,543,000	€ 3,954,300

As can be seen from this analysis, the economic value of A&D related formulation activities in terms of lost profits is estimated as being in the region of a few millions of Euros. These estimates should be considered illustrative as they reflect mixtures based on a single chromate. However, they provide an indication of the lower bound value of the market. This compares to the billions turnover and profits generated by the A&D industry under the continued use scenario, and the avoided costs to civil aviation and military forces (as discussed below).

4.3.2 The continued use scenario for the downstream A&D market

4.3.2.1 Summary

The A&D industry as represented by the major OEMs, DtBs, BtPs and MROs comprising the ADCR has separately and jointly assessed, and continues to review, its needs to ensure:

- the ability to carry out the specific processes required to manufacture, maintain and repair A&D components and products in the EEA; and
- the linked continuity of supply of critical products containing hexavalent chromium.

The requirements of the ADCR members – as downstream users - supporting this review report have been carefully identified and analysed, taking as the starting point the parent authorisations and the substance-use combinations covered by these. Over the lifetime of the ADCR consortium, the number of uses identified as requiring authorisation and the number of OEMs and downstream users supporting each use has decreased (including the individual chromate substances involved in a use), to ensure that authorisation is only sought for those cases where there is no substitute that is fully qualified as per stringent airworthiness requirements and industrialised by all members and their supply chains. The continual re-visiting of supply chain requirements fed into the narrowing of the substance-use combinations requiring re-authorisation compared to the original applications for authorisation.

The scope of this RR is driven by A&D qualification, validation and certification requirements, which can only be met by use of the mixtures that provide the required performance as mandated by airworthiness authorities. This constrains OEMs, DtBs, and hence their BtP suppliers and MRO facilities (civilian and military) to the use of the Cr(VI) mixtures until alternatives can be qualified and certified across all the relevant components. In many cases, the choice of the mixtures to be used is further affected by the fact that they form part of a surface treatment process flow, which has been developed over time to meet specific performance requirements as part of ensuring airworthiness

The assessments of the availability of alternatives provided in the individual, surface-treatment specific AoA-SEAs prepared for the ten uses of the chromates supported by the ADCR detail the importance of Cr(VI) to corrosion protection and the other key functions delivered by Cr(VI) containing mixtures. Although some of the ADCR members – as design owners – will have found alternatives to the continued use of these mixtures and implemented these at the industrial level for some components and products, they have not been able to do so across all of their uses and associated products. As a result, all members of the ADCR are supporting the authorisation of the continued use of the four chromates in formulation. This includes continued formulation for use in the manufacturing of components, as well as well as in MRO activities.

The continued use of the mixtures is also essential in the manufacture of legacy spare parts and where certification of components using alternatives is not technically feasible or available due to design control being held by Ministries of Defence, who will not revisit older equipment designs in the near future and rely on use of the mixtures to maintain the mission readiness of their equipment.

As a result, the continued use scenario for these A&D downstream users and their customers can be summarised as follows. This is based on the design owners' substitution plans, the longest review period being requested of the main surface treatments reliant on formulation activities continuing is 12 years (e.g. chemical conversion coating, electroplating).

Continued use of Cr(VII) mixtures while substitution plans for the downstream surface treatments are progressed	Continued use for production, repair and maintenance of parts and components
-> R&D on substitutes and progression through TRL 2/3 to 9 and to MRL10 continues	-> A&D sector retains and expands its EEA / UK manufacturing base
-> Downstream use continues in A&D supply chain as alternatives are certified and implemented	-> Industrialisation of substitutes and their adoption across supply chains
-> Modification of designs as substitutes are certified and industrialised	-> R&D into the adoption of more sustainable technologies continues
-> Update of Maintenance Manuals to enable substitution in MRO activities	-> Employment in the sector is retained while worker exposures and risks decline over time
-> Continued production, repair and maintenance of aircraft and other final products ensured	-> Impacts on civil aviation, emergency services and military mission readiness is minimised

4.3.2.2 The downstream A&D market

Size of the market

In 2020, the European A&D industry comprised over 3,000 companies of all sizes and employed over 880,000 highly skilled employees (with these figures including the UK[15]). A significant proportion of these companies will be involved in the use of chromate-containing mixtures, and those that are not involved in their direct use are likely to be linked to or reliant upon the activities of companies that either use the chromates themselves or have suppliers that do.

Notifications to ECHA, across the four chromates, indicate that in total the parent authorisations relevant to the A&D sector cover use of the chromates in one or more surface treatments at up to 400[16] downstream user sites across the EEA; it is estimated that between 30 and 50 A&D sites will be using the chromates in the UK. This suggests that around 15% (up to 450) of the 3,000 A&D companies are directly involved in the use of chromate-containing mixtures.

[15] Further information on the UK is provided in Annex 1.

[16] Note that this figure was derived from an analysis that included dichromium tris(chromate) authorisations; as some MRO sites in particular may only use DtC, this figure should be considered as an upper limit.

Some of these sites will be using only small quantities of the chromate mixtures, while others use much larger quantities and more than one chromate-containing mixture. At some sites – civilian and military – mixtures containing all four chromates will be essential to the range of manufacturing or maintenance and repair activities carried out.

Economic importance of the market

As noted by the European Commission, the industry is "characterised by an extended supply chain and a fabric of dynamic small-, medium-, and large enterprises throughout the EU, some of them world leaders in their domain"[17]. **Figure 4-1** provides details of turnover and employment for the industry in 2020, based on the AeroSpace and Defence Industries Association of Europe (ASD) publication "2021 Facts & Figures".[18]

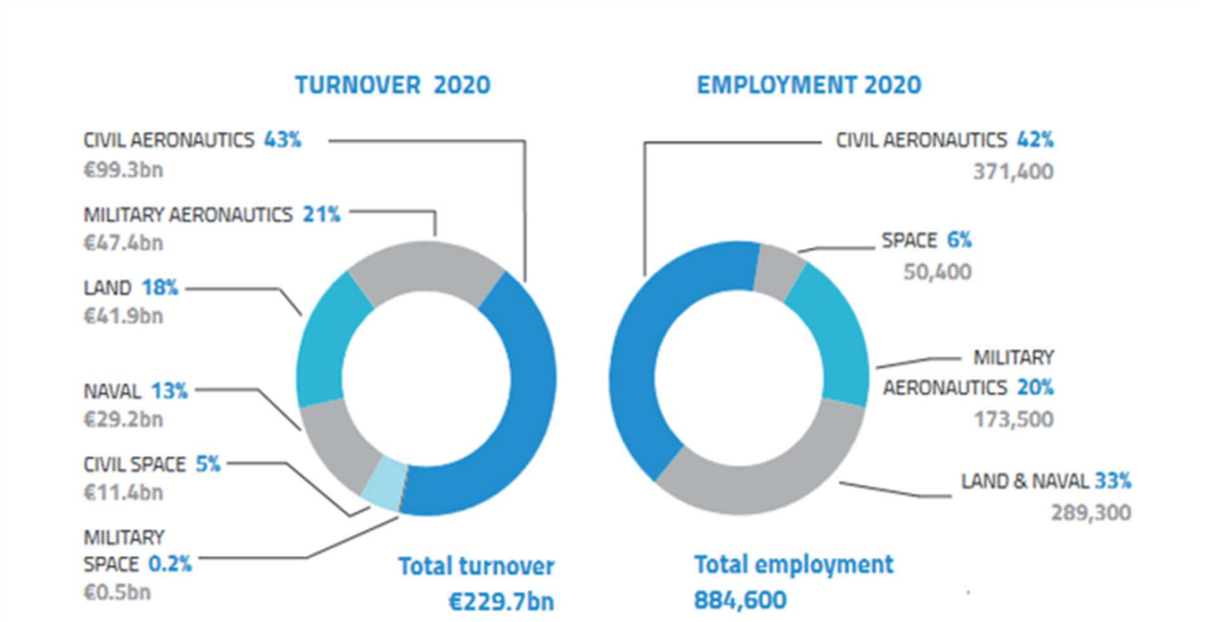

Figure 4-1: Turnover and Employment for the European Aerospace and Defence Industry in 2020
Based on ASD, 2021, available at: https://www.asd-europe.org/sites/default/files/atoms/files/ASD_Facts%26Figures_2021_.pdf

As can be seen from **Figure 4-1**, civil and military aeronautics alone accounted for 64% of turnover and 62% of employment for the sector in 2020.

Civil aeronautics alone accounted for over 370,000 jobs, revenues of over €99.3 billion and exports of €88.3 billion. Note, these figures are lower than those for 2019, reflecting the impacts of Covid-19 on the sector. For example, the 2019 figures for civil aeronautics were around 405,000 jobs and €130 billion in revenues, with exports amounting to around €109 billion.

17 https://ec.europa.eu/defence-industry-space/eu-aeronautics-industry_en

18 ASD, 2021: Facts & Figures, available at: https://www.asd-europe.org/facts-figures

The defence industry accounted for around 462,000 jobs, revenues of over €119 billion and exports of €45.6 billion. These figures reflect reductions in exports, employment and revenues compared to 2019, stemming from the impacts of COVID-19 on the sector.

The A&D sector is recognised as important to the ongoing growth and competitiveness of the EU and UK economies. It is also recognised that both require long-term investments, with aircraft and other equipment being in service and production for several decades:

- Aircraft and other A&D products remain in service over long time periods. For example, the Boeing 747 first entered service in 1970, and continues to be flown and produced in 2022 (although it will now go out of production but remain in service). Given the need to ensure on-going airworthiness and due to certification requirements, there will continue to be a "legacy" demand for the use of chromates in the production of components for maintenance, repair and overhaul of existing aircraft and equipment, as well as for models that are still in production long periods after the first aircraft or military products were placed on the market;

- A&D technologies take many years to mature. Product development is a five- to ten-year process, and it can take 15 years (or more) before the results of research projects involving the testing and development of new formulations are applied in the market. As part of the development and roll-out of new A&D products, OEMs must be ready to demonstrate fully developed technologies, or they risk losing contracts that may have a lasting effect on business.[19]

- The long product development process applies not only to the introduction of new technologies, but also to any activities aimed at adapting existing technologies as required for the substitution of the safety critical uses of the chromates. Research on substitution of the chromates has been underway for several decades, with the development of substitute mixtures underway but proving difficult for many surface treatments, in part due to the fact that these mixtures are used in surface treatment process flow with other surface treatments.

- There are over 20,000 commercial aircraft and 15,000 business jets currently in operation globally. Given the global nature of civil aviation, it is important that global solutions are found to the use of chromate-containing mixtures, with respect to maintenance, overhaul and repair operations (MRO). Actors involved in MRO activities must adhere to manufacturers' requirements and ensure that they use certified components and products. They have no ability to substitute away from the chromates where these are mandated by the original equipment manufacturers.

A&D products must operate safely and reliably, across different geographies, often in extreme temperatures and precipitation, and in aggressive environments with a high risk of corrosion (due to extreme temperatures, precipitation, salt spray and altitudes). Because the chromate-containing mixtures cannot be fully substituted at present, they play a critical role in ensuring the reliability and safety of final products.

[19] ATI (2017): The Economics of Aerospace: The Economic Impacts of UK Aersopace Industrial Strategy.

Thus, although the economic importance of the formulated mixtures is indirect in nature, its significance is clear with respect to ensuring that aircraft retain their airworthiness, given the importance of the sector to the transport of passengers and cargo, and hence the EEA and UK economies (for example, then number of air passengers transported in the European Union in 2019 was over 1 billion).

Growth in the civilian market

Furthermore, as detailed in the various surface treatment AoA-SEAs, the continued availability of the chromate-based mixtures over the requested review period will help ensure that the EEA/UK A&D industries are able to respond to the global demand for new aircraft and defence equipment. The European aerospace sector is a global exporter of aircraft, and A&D products make a significant contribution to the overall balance of trade. For example, France and Germany alone had export markets totalling over US $57 billion (£41 billion) in 2020, while the UK export market was around US $13.2 billion (£9.6 billion) in 2020.[20]

The demand for civilian aircraft is expected to grow between 2020 and 2031 at a compound annual growth rate of 2.5%[21], with the growth rate for passenger air traffic projected at between 3.6% and 3.8%[22] (see also the other review reports submitted by the ADCR). Under the continued use scenario, EEA/UK A&D companies would be able to expand their manufacturing output so as to achieve the levels of growth implied by these compound annual growth rates. This would result in increased growth for the EEA and UK economies, due to increased turnover, retained profits and employment. It also means that the EEA and UK would continue to benefit from any increases in technological know-how associated with the move to newer generation aircraft.

Growth in the aftermarket parts segment would also be maintained. The aircraft spare components/final product market encompasses the market for both new and used rotable[23] components available as spares for aircraft and other products. This market was projected to grow with a CAGR of over 4% over the period from 2022-2027, although this rate may now be lower due to Covid-19. Growth is due to the increase in the commercial aircraft fleet as well as the need for timely MRO services to keep aircraft in-service.

Similarly, the MRO market is expected to have a CAGR of over 3% over the period from 2022-2027.[24, 25] This growth is due to three factors: 1) Airlines are risk averse and try to maintain their fleets in an optimum condition, so as to delay the need to procure new aircraft, owing to the high investment

20 https://www.statista.com/statistics/263290/aerospace-industry-revenue-breakdown/

21 Oliver Wyman Analysis (2021): https://www.oliverwyman.com/our-expertise/insights/2021/jan/global-fleet-and-mro-market-forecast-2021-2031.html

22 https://www.airbus.com/sites/g/files/jlcbta136/files/2022-07/GMF-Presentation-2022-2041.pdf; https://www.boeing.com/commercial/market/commercial-market-outlook/index.page

23 A component which is removed and replaced at pre-determined intervals measured in elapsed flight hours and/or flight cycles after which the removed item is sent for overhaul and will be subsequently re-used.

24 Mordor Intelligence, Commercial Aircraft Maintenance, Repair, and Overhaul (MRO) Market – Growth, Trends, Covid-19 Impact and Forecasts (2022 - 2027)

25 Oliver Wyman analysis: at: A forecast update on the global commercial airline fleet and aftermarket for 2020

costs of such aircraft - with COVID-19 severely impacting revenues and profit margins, more airlines are expected to resort to MROs to maintain fleet efficiency; 2) Airlines face very stringent MRO requirements so are not able to postpone MRO requirements; and 3) Increases in fleet sizes over the next 5 years will also lead to a continued growth in demand for maintenance and repair activities.

Growth in the defence sector

The military importance of ensuring that military aircraft, land and naval hardware maintain their mission readiness cannot be quantified; however, the involvement of MoDs (as well as the MROs supporting military forces) in the ADCR through the provision of information that demonstrates the critical nature of chromate-based mixtures to the on-going preparedness of their military forces in particular.

The war in Ukraine has led to several EEA countries and the UK to revisit their defence expenditure. In particular, several countries that are NATO members and which previously did not meet the target of spending 2% of GDP on defence are now committed to meeting that target. This compares to Eurostat figures for total general government expenditure on defence in 202 of around 1.3% of GDP for the EU[26]. The increase in investment will equate to hundreds of billions of Euros (e.g. Germany alone has pledged €100 billion in defence spending). Similarly, defence spending in the UK is expected to increase to over 2%, with projections in June 2022 suggesting 2.3% of GDP but Government commitments announced in October 2022 aiming for a target of 3% of GDP by 2030[27]. This equates to an increase in spending of around £157 billion between 2022 and 2030.

Such investment, which will include new spending on existing technologies, may also result in a continued reliance on the use of the chromate-based mixtures in the short to medium term until alternatives are certified for use in the manufacture of the relevant components and final products.

With respect to currently in-service products, the global military aviation maintenance, repair, and overhaul market registered a value of US $38 billion (€32 billion, £28 billion) in 2021, and it is expected to register a compound annual growth rate (CAGR) of over 2.5% during the forecast period 2022-2031. The European segment of this market is the fastest growing segment.

4.4 Risks associated with continued use

4.4.1 Classification and exposure scenarios

4.4.1.1 Human health classifications

The chromates shown were included into Annex XIV of Regulation (EC) No 1907/2006 due to their intrinsic properties (mutagenic, carcinogenic, toxic for reproduction, depending on the chromate).

Chromium trioxide is classified as a Carcinogen 1A and a Mutagen 1B under the CLP Regulation. The most important route of exposure and target organs are inhalation causing lung cancer and oral

[26] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Government_expenditure_on_defence

[27] https://www.bloomberg.com/news/articles/2022-09-25/defence-spending-to-increase-by-at-least-52bn-in-response-to-russian-aggression or https://rusi.org/explore-our-research/publications/occasional-papers/famine-feast-implications-3-uk-defence-budget

exposure causing intestinal cancer. The substance is also classified as a Skin and Respiratory Sensitiser 1 and is a Reproductive Toxicant 2.

Sodium dichromate is classified as a Carcinogen 1B and a Mutagen 1B under the CLP Regulation. The most important route of exposure and target organs are inhalation causing lung cancer and oral exposure causing intestinal cancer. The substance is also classified as a Skin and Respiratory Sensitiser 1 and a Reproductive Toxicant 1B.

Potassium dichromate is classified as a Carcinogenic 1B, a Mutagen 1B, and as a Reproductive toxicant 1B under the CLP Regulation. The most important route of exposure and target organs are inhalation causing lung cancer and oral exposure causing intestinal cancer. It is also classified as a Skin and Respiratory Sensitiser 1.

Dichromium tris(chromate) (DtC) is classified as a Carcinogen 1B and as a Skin Sensitiser 1. As for the other chromates, the most important route of exposure is inhalation causing lung cancer

Reproductive toxicity for the above chromates is an effect of oral exposure. However, according to information from the Chemical Safety Report (CSR), the calculated exposure levels were below the DNEL for reproductive toxicity. Therefore, the risks associated with that endpoint are considered adequately controlled and as such it will not be examined further in this SEA.

4.4.1.2 Overview of exposure scenarios

Due to the different levels in the supply chain to which the individual companies may be associated, and the variation in the size of the sites, the conditions under which the use is carried out can be variable. The conditions of use cover small sites and repair shops with rare and infrequent applications up to large sites with high throughput, and thus, a low to high level of automation for specific activities. This variability was also observed in extensive consultation processes during the preparation of the CSR. As displayed in the table below is all the exposure scenarios (ES) and contributing scenarios assessed in the CSR.

Table 4-9: Overview of exposure scenarios and their contributing scenarios

ES number	ES Title	Environmental release category (ERC)/ Process category (PROC)
ES1-F1	Formulation of mixtures with soluble Cr(VI) compounds	
Environmental contributing scenario(s)		
ECS 1	Formulation into mixture	ERC2
Worker contributing scenario(s)		
WCS 1	Operators producing liquid mixtures	PROC 5, 8a, 8b, 9, 28
WCS 2	Operators producing solid mixtures	PROC 5, 8a, 8b, 9, 28
WCS 3	Laboratory technicians	PROC 15
WCS 4	Maintenance workers	PROC 28
WCS 5	Logistics operators	PROC 8b
WCS 6	Incidentally exposed workers	PROC 0
Exposure scenario for formulation: ES1-F1		

All sites adhere to best practices to reduce workplace exposures and environmental emissions to as low as technically and practically feasible and use automated processes to the extent possible. The possibility for and the degree of automation can vary between different sites and depend, amongst other factors, on the size of the site and the frequency with which the use in question is carried out.

4.4.2 Exposure and risk levels

4.4.2.1 Worker assessment

The complex process of formulating mixtures is outlined in detail in the CSR. As described in the CSR, there are five worker contributing scenarios to the exposure scenario for formulation. These are explained in more detail in the CSR and include:

- WCS1: Line operators producing liquid mixtures
- WCS2: Line operators producing solid mixtures
- WCS3: Laboratory technicians
- WCS4: Maintenance workers
- WCS5: Logistics operators
- WSC6: Incidentally exposed workers

As outlined in the CSR, the relevant human exposure pathways at the production facilities are chronic inhalation and dermal exposure. The CSR concludes that the dermal pathway is negligible in the context of the total exposure. Therefore, inhalation exposure is the only pathway relevant to worker exposure that is considered in this SEA. Total cancer risks for inhalation exposure are calculated by adding up risk estimates for the two main tumour body locations (bladder and lung).

Table 4-10 sets out the excess lifetime cancer risk for workers involved in each of the above tasks. It also indicates the number of workers on average exposed per site. These figures are based on the data collected for the CSR from the sites undertaking formulation activities specific to the A&D sector form the basis for determining the number of workers exposed to the chromates. These figures will be lower than Article 66 notifications data where these also cover formulation for uses in mixtures consumed by other sectors.

Table 4-10: Excess lifetime cancer risk estimates for workers

WCS #	Group of workers	Average number of workers exposed per site	Excess lifetime lung cancer risk [1/ ug /m^3)
WCS1	Line operators producing liquid mixtures	3 per site / max. 15 workers	1.74E-03
WCS2	Line operators producing solid mixtures	4 per site / max. 4 workers (1 site)	5.60E-4
WCS3	Laboratory technicians	3 per site	Exempt
WCS4	Maintenance workers	2 per site / max. 10 workers	5.88E-4
WCS5	Logistics operators	2 per site / max. 10 workers	2.14E-04
WCS6	Incidentally exposed workers	2 per site / max. 10 workers	2.00E-03
Total		**9 to 13 per site excluding lab technicians**	-

Source: CSR
Note: Excess lung cancer risk refers to 40 years of occupational exposure

4.4.2.2 Humans via the environment

Excess lifetime cancer risks

The assessment of risks for humans via the environment presented in the CSR has been carried out for the general population at the local level only. No regional assessment has been carried out as it can be assumed that Cr (VI) from any source will be reduced to Cr (III) in most environmental situations and therefore the effects of Cr (VI) as such are likely to be limited to the area around the source, as described in the EU Risk Assessment Report for chromates (ECB, 2005). The approach to not perform a regional assessment for human Cr (VI) exposure via the environment as part of AfAs for chromate uses was also supported in compiled RAC and SEAC (Socio-economic Analysis Committee) opinions, as described for example in the Opinion on an Application for Authorisation for Use of Sodium dichromate for surface treatment of metals such as aluminium, steel, zinc, magnesium, titanium, alloys, composites and sealings of anodic films (ID 0043-02). This reference states that regional exposure of the general population is not considered relevant by RAC.

The CSR takes into account measured data for emission to air and wastewater, and provides estimates of the combined exposure of humans via the inhalation (air) and the oral (uptake of water and fish) route is considered. The resulting 90th percentile risk estimates are presented in the table below, with the maximum used in the assessment of residual cancer cases.

Table 4-11: Excess lifetime cancer risk estimates for humans via the environment (general population, local assessment)

	Inhalation		Oral		Combined
	Local Cr (VI) PEC in air [µg/m3]	**Inhalation risk**	**Oral exposure [µg Cr (VI)/kg x d]**	**Oral risk**	**Combined risk**
MIN	**9.03E-07**	**2.62E-08**	**1.32E-07**	**1.06E-10**	**3.78E-08**
MAX	**4.28E-05**	**1.24E-06**	**7.55E-05**	**6.04E-08**	**1.24E-06**

a RAC dose-response relationship based on excess lifetime lung cancer risk (ECHA, 2013): Exposure to 1 µg/m3 Cr (VI) relates to an excess risk of 2.9x10-2 for the general population, based on 70 years of exposure; 24h/day.
b RAC dose-response relationship based on excess cancer risk for tumours of the small intestine (ECHA, 2013): Exposure to 1 µg/m3 Cr(VI) relates to an excess risk of 8x10-4 for the general population, based on 70 years of exposure; 24h/day.

Exposed local populations

Exposure to the general population can happen via the environment by means of inhalation and oral exposure. The relevant local population for humans via the environment has been estimated based on the following information:

- Number of downstream user sites in total and then as assumed in terms of their distribution across the EU / EEA
- The population density per km^2 for each relevant EU / EEA member state
- The relevant distance from sites for the local assessment, taken as the default assumption of a 1000m radius (or 3.14 km^2).

The resulting estimates of the number of people exposed within the general population are given in **Table 4–12** for the EEA and UK. The total number of humans exposed via the environment in the EEA is estimated at 3,069, while the figure for the UK is 2,664. The distribution of sites in the EEA is based on the percentages of Article 66 notifications made by sites in the different EEA countries specific to functional chrome plating.

As noted above, no assessment of risks for humans via the environment at the regional level has been carried out based on RAC's previous opinion that regional exposure of the general population is not relevant.

Table 4–12: General public, local assessment exposed population from CCC across the EEA and UK

Countries with DUs	No. Sites per country	Population density per km^2	Exposed local population within 1000m radius
Germany	2	232	1,458
Netherlands	1	421	1,323
Spain	1	92	289
Total EU	**4**		**3,069**
Total UK	2	424	2,664

4.4.3 Residual health risks

4.4.3.1 Introduction

Under the continued use scenario, use of chromates for formulations will continue after the end of the Review Period for a total of 12 years.

In December 2013, the Risk Assessment Committee (RAC) agreed lifetime (i.e., for 40 years and 70 years of exposure) mortality risk estimates associated with carcinogenicity for workers and humans via the environment exposed to Cr (VI) substances. It assumes a linear relationship for both lung and intestinal cancer.

As the excess cancer risk estimates apply to each exposed worker for a total working life of 40 years, they need to be adjusted to reflect exposures over the length of the review period. Exposures are thus treated as separable over time, meaning that annual risk is equivalent to 1/40 of the risk over 40 years of exposure. For members of the general population, excess cancer risks estimates apply for a lifetime of 70 years, meaning that annual risk is equivalent to a 1/70 of the risk of 70 years of exposure.

4.4.3.2 Morbidity vs Mortality

Excess cancer cases need to be split between fatal and nonfatal ones. To this end, estimates of fatality and survival rates associated with lung and colorectum cancer cases were derived from the Cancer Today database, see Table 4–13 below.

Table 4–13: Estimated incidence and mortality of cancers across the EU-27 and the UK, both males and females (in 2020)			
Type of cancer	**Cases**	**Deaths**	**Survivals**
Lung	370,310	293,811 (79%)	76,499 (21%)
Colorectum (intestinal)	393,547	177,787 (45%)	215,760 (55%)
Source: Source: http://gco.iarc.fr/today/home (accessed on 20/02/2022) Note: Percentages have been rounded			

To calculate the number of additional non-fatal lung cancer cases, a ratio of deaths to survivals is applied to the number of additional fatal lung cancer cases, as shown below:

(1) $\mathbf{(0.21/0.79) \times \pi = \sigma}$

where π is the number of additional fatal lung cancer cases and σ is the number of additional non-fatal lung cancer cases.

In a similar fashion, the figures from Cancer Today reported Table 4–13 above are applied to the estimates to calculate the total number of additional fatal and non-fatal intestinal cancer cases.

(2) $\mathbf{(0.55/0.45) \times \delta = \eta}$

where, δ is the number of additional fatal intestinal cancer cases and η is the number of additional non-fatal intestinal cancer cases.

4.4.3.3 Predicted excess cancer cases with continued use: workers directly exposed

Total excess cancer risk cases are calculated per line to reflect differences in activities, task allocation and exposure levels across the different sites. The number of excess risk cases are calculated by multiplying the number of workers expected to be exposed in each task by the value of the excess cancer risk given above adjusted for the requested review periods, i.e., over 12 years. This value is then multiplied by the number of workers exposed in each SEG to calculate the total excess cancer cases arising from the continued use of chromates in formulation activities.

Table 4-14: Number of excess lifetime cancer cases to EU workers					
WCS	**Number of persons exposed**	**LUNG CANCER - Excess lifetime cancer risk**	**Excess number of lifetime cancer cases**	**LUNG CANCER - Number of excess lifetime fatal cancer cases**	**LUNG CANCER - Number of excess lifetime non-fatal cancer cases**
WCS1	12	1.74E-03	**0.021**	**0.016**	**0.004**
WCS2	4	5.60E-04	**0.002**	**0.002**	**0.000**
WCS4	8	5.88E-04	**0.005**	**0.004**	**0.001**
WCS5	8	2.14E-04	**0.002**	**0.001**	**0.000**
WCS6	8	2.00E-03	**0.016**	**0.013**	**0.003**
		Years - Lifetime	**40.00**	**0.036**	**0.010**
		Years - Review period	**12.00**	**0.011**	**0.003**
		Years - Annual	**1.00**	**0.001**	**0.000**

Table 4-15: Number of excess lifetime cancer cases to UK workers					
WCS	Number of persons exposed	LUNG CANCER - Excess lifetime cancer risk	Excess number of lifetime cancer cases	LUNG CANCER - Number of excess lifetime fatal cancer cases	LUNG CANCER - Number of excess lifetime non-fatal cancer cases
WCS1	6	1.74E-03	**0.010**	**0.008**	**0.002**
WCS2	0	5.60E-04	**0.000**	**0.000**	**0.000**
WCS4	4	5.88E-04	**0.002**	**0.002**	**0.000**
WCS5	4	2.14E-04	**0.001**	**0.001**	**0.000**
WCS6	4	2.00E-03	**0.008**	**0.006**	**0.002**
		Years - Lifetime	**40.00**	**0.017**	**0.005**
		Years - Review period	**12.00**	**0.005**	**0.001**
		Years - Annual	**1.00**	**0.000**	**0.000**

4.4.3.4 Predicted excess cancer cases with continued use: humans via the environment

The total number of people exposed as humans via the environment as given in **Table 4–12** is multiplied by the excess cancer risk estimates to calculate the total excess cancer cases arising under the continued use scenario. The results are given in **Table 4–16**.

Table 4–16: Excess lifetime cancer risks for the general public (local assessment) across the EEA and UK							
Countries with formulation sites	**No. sites per country**	**Population Density per km2**	**Exposed local population**	**Combined excess lifetime cancer risk**	**Excess number of lifetime cancer cases**	**Number of excess lifetime fatal cancer cases**	**Number of excess lifetime non-fatal cancer cases**
Germany	2	232	1458	1.24E-06	1.81E-03	**1.43E-03**	**3.80E-04**
Spain	1	92	289	1.24E-06	3.58E-04	**2.83E-04**	**7.53E-05**
Netherlands	1	421	1323	1.24E-06	1.64E-03	**1.30E-03**	**3.44E-04**
Total EEA	**4**		**3,069**	1.24E-06	3.81E-03	**3.01E-03**	**7.99E-04**
			Years – Lifetime cases		**70.00**	**3.01E-03**	**4.55E-04**
			Years - Review period		**12.00**	**5.15E-04**	**1.37E-04**
			Years - Annual		**1.00**	**4.30E-05**	**1.14E-05**
UK	**2**	424	2,664	1.24E-06	3.30E-03	**2.61E-03**	**6.94E-04**
			Years - Lifetime		**70.00**	**2.61E-03**	**6.94E-04**
			Years - Review period		**12.00**	**4.47E-04**	**1.19E-04**
			Years - Annual		**1.00**	**3.73E-05**	**9.91E-06**

4.4.4 Economic valuation of residual health risks

4.4.4.1 Economic cost estimates

In order to monetise human health impacts, a timeframe that goes from the end of 2024 to the end of 2036 (i.e. a 12-year review period) has been used and a 4% discount rate has been employed for calculating net present values[28]. It has been assumed that the levels of exposure to Cr (VI) for workers and members of the general population remains constant throughout the length of the review period, although this is a very conservative assumption. In fact, downstream users will gradually reduce the amount of Cr (VI) consumed as the transition to the alternative (CFPA) proceeds.

The economic valuation of the health impacts takes into account two important welfare components, the costs associated with mortality and morbidity. The basis of our calculations is the study led by the Charles University in Prague and undertaken for ECHA.

The economic valuation of the health impacts considers two important welfare components, the costs associated with mortality and morbidity.

The basis of our calculations is the study led by the Charles University in Prague[29] and undertaken for ECHA. This study was critically reviewed by ECHA in 2016 and the results of that review have been the basis of the economic valuation performed here[30].

The values utilised are:

- **Value of statistical life for the avoidance of a death by cancer:** €3.5 million (2012 prices) and
- **Value of cancer morbidity:** €0.41 million (2012 prices)

It is important to update the figures above to 2021 prices. This can be achieved by utilising the EU GDP deflator[31]. This suggests that the aforementioned figures should be multiplied by a factor of 1.1200. Therefore, the following values are in the methodology below:

- **Value of statistical life (mortality)**: €3.5 million x 1.1200 = €3, 920,000 (rounded); and
- **Value of cancer morbidity:** €0.41 million x 1.1200 = €0.46 million

In addition to these valuations, for the purpose of quantifying human health impacts, consideration has also been given to annual medical treatment costs for morbidity. A range of studies were identified that provide estimates of the costs of medical treatment for patients surviving lung and intestinal cancer.

28 EC Better Regulation Toolbox – Tool #61: https://ec.europa.eu/info/sites/default/files/file_import/better-regulation-toolbox-61_en_0.pdf

29 Alberini, A. and Ščasný, M. (2014) Stated - preference study to examine the economic value of benefits of avoiding selected adverse human health outcomes due to exposure to chemicals in the European Union - Part III: Carcinogens.

30 ECHA (2016b) Valuing selected health impacts of chemicals. Available at: http://echa.europa.eu/contact

31 https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=teina110&plugin=1

Table 4-17: Alternative estimates of medical treatment costs			
Study	Year for prices	Average direct costs in original units (per annum)	Direct costs in € 2021
Lung cancer[32]			
Leal (2012)	2012	£9,071	€11,160
Braud et al (2003)	2001	€12,518	€15,800
Dedes et al (2004)	1999	€20,102	€23,460
Intestinal cancer (colon, colorectal and rectal cancer taken as proxies)[33]			
Luo et al (2010)	2000 (assumed)	US$29,196	€36,230
Lang et al (2009)	2006	US$28,626	€31,740
York Health Economics Consortium (2007)	2004	£8,808	€12,180
York Health Economics Consortium (2007)	2004	£12,037	€16,410

The average cost across the four lung cancer studies is €17,314 per annum (2021 prices). The average cost figures reported for intestinal cancer are based on figures produced for colon, rectal and colorectal cancer in the US and UK. The US figures are high compared to the UK data; as a result, the average across the two UK studies is taken here, with this being around €14,853 per case in 2021 prices, considering price inflation.

These average medical costs are annual figures and apply to survivors over the period of time that they continue to be treated. With respect to lung cancer morbidity cases, we have taken a percentage survival of 32% after 1 year since diagnosis, 10% after 5 years, 5% after 10 years[34]. With respect to intestinal cancer morbidity cases, we have taken a percentage survival of 76% after 1 year since diagnosis, 59% after 5 years, 57% after 10 years[35]. Based on these time periods, the NPV of average future medical costs per lung cancer case is estimated at €30,110 in 2021 prices, using a 4% future discount rate. The NPV of average future medical costs per intestinal cancer case is estimated at €82,620 in 2021 prices. It is noted that a large percentage of people survive intestinal cancer after a period of 10 years and any stream of health care costs incurring after that is not incorporated in our calculations. However, such costs are not likely to be relevant considering that those surviving

[32] Leal, J., 2012. Lung cancer UK price tag eclipses the cost of any other cancer, presentation by Health Economics Research Centre, University of Oxford to the NCIR Cancer Conference, Wednesday, 7 November. s.l.:s.n. Braud, L. & al, 2003. Direct treatment costs for patients with lung cancer from first recurrence to death in France. Pharmacoeconomics, 21(9), pp. 671-679. Dedes, K. J. & al, 2004. Management and costs of treating lung cancer patients in a university hospital. Pharmacoeconomics, 22(7), pp. 435-444.

[33] Luo, Z. & al, 2010. Colon cancer treatment costs for Medicare and dually eligible beneficiaries. Health Care Finance Review, 31(1), pp. 33-50. Lang, K. & al, 2009. Lifetime and Treatment-Phase Costs Associated with Colorectal Cancer: Evidence from SEER-Medicare Data. Clinical Gastroenterology and Hepatology, Volume 7, pp. 198-204. York Health Economics Consortium, 2007. Bowel Cancer Services: Costs and Benefits, Final Report to the Department of Health, April 2007, York: University of York.

[34] These values are based on a study conducted by Cancer Research UK on adults aged 15-99 in England and Wales. https://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/lung-cancer/survival.

[35] These values are based on a study conducted by Cancer Research UK on adults aged 15-99 in England and Wales from 2009-2013. https://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/bowel-cancer/survival#heading-Zero

after such a long period of time can either be considered as definitely cured or probably only in need of a small degree of medical attention.

The valuations of mortality and morbidity were multiplied by the estimated number of additional cancer cases, fatal and non-fatal, that can occur in the Applied for use scenario. The basic calculations for the value of an excess cancer case are presented below:

(1) $(\pi \times (€\ 3{,}920{,}000)) + (\sigma \times (€\ 460{,}000 + €\ 30{,}110)$ = **Total lung cancer costs**

(2) $(\delta \times (€\ 3{,}920{,}000)) + (\eta \times (€\ 460{,}000 + €82{,}620))$ = **Total intestinal cancer costs**

With respect to the timing of the cancer effects, these are first assumed to occur in 20 years' time and then occur for an additional 12 years corresponding to the applied for review period.

4.4.4.2 Predicted value of excess cancer cases with continued use: workers

The costs associated with mortality and morbidity are applied to the estimated annual number of excess statistical fatal and non-fatal cases for workers at the four sites undertaking formulation in the EEA and two sites in the UK. The annual human health costs are then discounted following a 20 year lag over a 12-year period, at a rate of 4%.

Table 4-18: Present value and annualised economic value of mortality and morbidity effects to workers (discounted over 12 years @4% per year, 20 year lag, figures rounded)

	EU Workers		UK Workers	
	Mortality	Morbidity	Mortality	Morbidity
Total number of lung cancer cases	1.08E-02	2.87E-03	5.13E-03	1.36E-03
Annual number of lung cancer cases	8.99E-04	2.39E-04	4.28E-04	1.14E-04
Present Value (PV, 2024)	€ 15,271	€ 476	€ 7,260	€ 226
Total PV costs	**€ 15,747**		**€ 7,486**	
Total annualised cost	**€ 3,635**		**€ 1,728**	
Source: Study team analysis				

4.4.4.3 Predicted value of excess cancer cases with continued use: man via the environment

The selected values for mortality and morbidity were applied to the estimated annual number of excess statistical fatal and non-fatal cancer cases amongst the general population. The annual human health costs are then discounted from year 20 over 12 years at a rate of 4%. The results are given in the table below, including the estimated number of cancer cases and associated costs in present value terms over the 12-year assessment period.

Table 4-19: Present value and annualised economic value of mortality and morbidity effects to the general population, local assessment (discounted over 12 years @4% per year, 20 year lag, figures rounded)				
	EU General Population		UK General Population	
	Mortality	Morbidity	Mortality	Morbidity
Total number of cancer cases	5.15E-04	1.19E-04	4.47E-04	1.19E-04
Annual number of cancer cases	4.30E-05	1.14E-05	3.73E-05	9.91E-06
Present Value (PV, 2024)	€ 729	€ 25	€ 633	€ 22
Total PV costs	**€ 754**		**€ 655**	
Total annualised cost	**€ 174**		**€ 151**	
Source: Study team analysis				

4.4.5 Human health impacts for workers at downstream user sites

The human health impacts associated with use of the formulated mixtures at A&D sites in the EEA and UK are assessed in each of the dossiers submitted by the ADCR for the ten surface treatment activities essential to the A&D sector.

4.4.6 Summary of human health impacts

Table 4-20 provides a summary of the economic value of the human health impacts across the worker and local populations. These estimates are specific to formulation activities relevant to mixtures used by the A&D sector at four sites in the EEA and two sites in the UK.

Table 4-20: Combined assessment of health impacts to workers and general population value of mortality and morbidity effects to workers (discounted over 12 years @4% per year, 20 year lag, figures rounded)				
	EU		UK	
	Mortality	Morbidity	Mortality	Morbidity
Total number of cancer cases	1.13E-02	2.99E-03	5.58E-03	1.48E-03
Annual number of cancer cases	9.42E-04	2.50E-04	4.65E-04	1.24E-04
Present Value (PV, 2024)	1.60E+04	5.01E+02	7.89E+03	2.48E+02
Total PV costs	**€ 16,501**		**€ 8,141**	
Total annualised cost	**€ 3,809**		**€ 1,879**	
Source: Study team analysis				

4.5 Environmental impacts

Releases to the environment are governed by, and comply with, local worker and environmental regulatory requirements. As a result, environmental impacts should be minimised under the continued use scenario.

Releases of wastewater containing Cr(VI) may occur from cleaning water and wash water from wet scrubbers. At all sites wastewater is collected and then treated by one or more of the following three options:

- Sending it to an external waste management company where it is treated as hazardous waste;
- Recycling and evaporation in an on-site evaporation system; the residue is discharged as hazardous solid waste;
- Discharge into a special treatment facility.

The special treatment facility is in most cases located on-site but may also be external where the water is transferred via underground pipes. Typically, contaminated water is either disposed as hazardous waste by an external company or conveyed to the special treatment facility. Wastewater from the other sources listed above is usually either collected and mixed together for treatment at the treatment facility or recycled and then led to the evaporation system. In the special treatment facility, the Cr(VI) in wastewater is reduced to Cr(III) by addition of a reducing agent (e.g., sodium metabisulphite, ferrous sulphate, or ferric chloride solutions) in excess of stoichiometry. Usually, reduction efficiency is measured by a redox probe. Following the reduction step, the wastewater pH is neutralized, and Cr(III) is precipitated. After monitoring of the Cr(VI) concentration in the reduced wastewater, usually the wastewater is mixed with other (non-Cr(VI)) containing waste solutions. The wastewater is then discharged to an external municipal wastewater/sewage treatment plant for further treatment prior to discharge to receiving waters (river, canal, or sea).

Exhaust air is released via stacks, and emitted air is treated in scrubbers or by air filters before being released to the ambient air. There are no direct releases to soil and solid waste materials containing Cr(VI) are classified and treated as hazardous wastes according to EU and national regulations. Any solid or liquid waste is collected and forwarded to an external waste management company (licenced contractor) for disposal as hazardous waste.

5 Socio-Economic impacts of the Non-use scenario

5.1 The Non-use scenario

5.1.1 Overview

The inability of companies to undertake chemical formulation activities across the EEA and in the UK using one or more of the four chromates would be severe. This use is critical to A&D industry as the resulting mixtures provide a range of key functions, including corrosion protection, chemical resistance, adhesion to subsequent layer, layer thickness, wear resistance, hardness and temperature resistance. The mixtures are used across a broad range of components and end products and cannot be substituted until alternatives are certified for use in the manufacture of those components and end products. They also cannot be substituted in maintenance, repair and overhaul activities until substitutes are certified for use in such activities and maintenance manuals are updated to this effect by A&D design owners.

It may be possible to import the mixtures used by the sector across the different surface treatments, however, it is likely that this would result in a move away from use of the aqueous mixtures to flake/powder mixtures. Use of the aqueous solutions reduces risks to downstream users in the handling and storage of materials, however. Furthermore, given that the chromates are contained in the mixtures at concentrations of 50% or less (and in many cases significantly less, this would result in a significant increase in transport requirements. Larger volumes of hazardous product would need to be imported and transported throughout the EEA compared to the import of the chromate substances followed by the shorter distances involved in transport of the formulated mixtures internally across Europe. This would increase both transport and logistic costs. This is especially the case if the imported mixtures would originate from the US, for example, to ensure that they met the stringent qualify control requirements of the A&D sector.

These imported mixtures would trigger the need for new certification activities. Any change in the source of the chromate or in the manufacturing of the mixtures will result in the need for their use to be newly qualified and certified for the manufacture of components and in maintenance and repair activities, due to the stringent airworthiness and safety and reliability requirements that must be met by the A&D sector. Even if such certifications could be achieved within a few months for each component (or families of similar components), the fact that this would be required across thousands of components would make it infeasible for OEMs and DtB companies.

Although some of the multi-chromate mixtures are used globally, these are the higher value, smaller volume products. Even in these cases, if the mixtures produced outside the EEA/UK rely on a different source of the chromates to those produced in the EEA/UK, then the A&D companies will have to qualify and certify the use of the new supply of the mixture in their manufacturing and repair activities.
The outcome, therefore, would be a relocation by the OEMs and major DtBs of some or all of their parts production and aircraft manufacturing activities out of the EEA/UK to locations where qualified and certified alternatives are currently available.

Further justification for this outcome is provided in the individual surface treatment AoA-SEA documents submitted as part of other ADCR review reports.

5.1.2 Summary of effects across the value chain

The series of events that would be triggered by formulation no longer being authorised include the following.

Formulation of Cr9VI)-based mixtures in the EEA/UK would cease

↓

The loss of such formulations would result in either relocation of manufacturing, maintenance and repair activities or the import of the chromate-based formulations

↓

The import of formulations would result in the need for new certifications due to potential changes in the source of the chromate or in manufacturing (and hence quality and other parameters)

↓

Gaining new certifications across all components and products would take years and would not be technically or economically feasible for downstream users on top of substitution efforts

↓

As a result, the major OEMs would relocate significant portions of their A&D manufacturing activities to countries where certified mixtures are available. This would also disrupt the current R&D being undertaken jointly by the formulators with their A&D customers

↓

Due to qualification and certification requirements, suppliers to the OEMs in the A&D value chain would be forced to relocate surface treatment activities involving use of Cr(VI)-based mixtures together with other manufacturing activities linked to those surface treatments, or to shift to suppliers outside of the EEA/UK where feasible (taking into account the fact that it would be costly to transport components and products outside the EEA / UK for surface treatment only, especially due to the need for rework and touch-up repairs.

↓

MROs, which make up a significant percentage of users, would have to shift at least some (if not most) of their activities outside the EEA, as use of Cr(VI) mixtures is an essential part of maintenance, repair and overhaul activities

↓

Relocation of MRO activities would cause significant disruption to the A&D sector itself as well as its customers

↓

Ministries of Defence would face logistical difficulties in maintaining aircraft and other equipment, severely impacting on mission readiness. Service agreements would need to be reached with non-EEA countries

↓

Civil aviation, passengers, freight shippers and emergency services would face reduced flight availability and routes, as well as increased costs

5.2 Economic impacts of non-use

5.2.1 Introduction

This section summarises the expected quantitative and qualitative economic impacts for all applicants/formulators of products, downstream users, competitors, and end customers under the non-use scenario. The primary social impacts considered are job losses at the formulators resulting from a cessation of their activities. Job losses downstream users' sites are not taken into account to avoid double-counting with those quantified for the ten surface treatment dossiers.

5.2.2 Economic impacts on formulators

Under the Non-use scenario, EEA/UK based formulators of products would be impacted by the loss of sales and therefore profits associated with the mixtures produced using chromium trioxide, sodium dichromate, potassium dichromate and sodium chromate either on their own or in combination.

As reported in Section 4.3.1, the economic value of the mixtures sold to the A&D industry is relatively low, in the order of several tens of millions per annum with profit levels assumed to be at around 10% of these. The economic value of the bulk mixtures over a 2 and 12-year period is given in Table 5-1. These figures should be treated as indicative; the actual level of profits will be higher than these figures. The share of the estimated profit losses to UK formulators would be less than 5%.

Note that the figures for the 12-year review period will represent an overestimate as they do not assume any decrease in use over the period from 2024 levels. Based on the substitution plans currently in place by the downstream users across the ten related surface treatments, reductions in use of the mixtures are already taking place and will increase over time as substitutes are qualified and certified for use in the manufacture, maintenance and repair of more and more components.

Table 5-1: Discounted value of sales and profits over 2 and 12 year periods (@ 4%) (EEA and UK combined)

	Tonnes used in 2024	Market value over 2 years	Profits over 2 years	Market value over 12 year period	Profits over 12 year period
Chromic acid solution	600	€ 47,527,200	€ 4,752,720	€ 236,502,000	**€ 23,650,200**
Sodium dichromate aqueous solution	100	€ 13,471,428	€ 1,347,142	€ 67,035,713	**€ 6,703,570**
Potassium dichromate aqueous solution	42	€ 13,579,200	€ 1,357,920	€ 67,572,000	**€ 6,757,200**
Totals		€ 74,577,828	€7,457,783	€371,109,713	**€37,110,970**

The value of the associated profit losses to formulators under the non-use scenario based on the above illustrative analysis is marginal compared to the economic impacts on downstream users and their customers. This is the key reason why the ADCR members have financed and supported this review report; the driving economic value associated with the continued formulation of the Cr(VI) mixtures is held by the downstream users.

Other economic costs may be incurred by the formulators, depending on whether or not authorisation is granted for the continued use of the chromates in the manufacture of formulations for non-A&D uses. Should formulation involving the chromates not be authorised for any uses, additional costs would be incurred from requirements regarding:

- Dismantling of existing equipment (decommissioning);
- Site decontamination, including e.g. soil remediation costs.

In addition to the above, the withdrawal of the formulated products from the market is likely to have an impact on the relationships between the formulators and A&D companies. This may result in the loss of market for other non-chromate based products (where companies like to find a "one-stop" supplier) and may impact on joint R&D programmes currently in place involving the formulators and the A&D companies.

5.2.3 Economic impacts on downstream A&D users

The economic impact on formulators compares to the billions in turnover and profits that would be lost under the non-use scenario to companies in the A&D sector, as well as to the disruption that would be caused to military forces in the EEA/UK reliant on the use of Cr(VI) mixtures in the maintenance, repair and overhaul of military (air, land and naval) equipment.

Shifting work involving Cr(VI) mixtures outside the EEA/UK to locations where certified uses of the chromates can continue is the most plausible scenario for most OEMs, DtB companies and MROs; most of the larger companies already have existing supply chains in other countries.

It would not be possible for companies involved in manufacturing of components and final products (or divisions of some of these companies) to maintain manufacturing activities downstream of surface treatment inside the EEA/UK, while transferring surface treatments involving use of the formulated mixtures outside the EEA/UK. This would result in huge numbers of transfers of components and products outside the EEA/UK for rework or touch-up, which would not be economically feasible. Furthermore, given the reliance on the use of Cr(VI) mixtures in supply chains, it is also the most likely response for the divisions which rely on their suppliers.

Similarly, it would not be feasible for MROs to undertake only maintenance, repair and overhaul activities excluding use of Cr(VI)-containing mixtures in the EEA/UK. When aircraft or equipment go in for repair and overhaul in particular, an MRO will have no clear idea of the full range of surface treatments that may be required; similarly, many maintenance activities will also involve use of a chromate-based mixture, even if only for touch-up or minor repairs. As a result, MROs will have to establish non-EEA/UK based sites that can undertake the full range of potential services involving the continued use of the chromates.

The economic cost of moving manufacturing or maintenance and repair activities and creating new supply chains has not been estimated for the purposes of this SEA. However, the economic costs to the EEA/UK from gross value added, turnover and profits have been estimated for the different surface treatment uses of the Cr(VI) mixtures. The figures are given in the combined AoA-SEA documents submitted to support the review reports submitted by the ADCR for the ten surface treatments where the continued use of the chromates is required for up to 12 years.

These figures highlight the enormity of the losses that would occur to the EEA/UK economies under the non-use scenario, due to the loss of the mixtures which are qualified and certified for use in the manufacture of A&D components and final products before alternatives have gone through qualification and certification.

By way of example, **Table 5-2** presents the estimated lost profits (lower and upper bound) that would occur should four of the ten surface treatments no longer be authorised. These same losses would also occur should formulation of the mixtures used in these processes no longer be authorised (note with the exception of any losses linked to use of DtC as part of chemical conversion coating).

Table 5-2: Lost profits to A&D companies from a refused authorisation (2 years @4%)

Surface treatment	Relevant chromates[1]	Number of sites	Profit losses (2 years, lower and upper bound estimates)
Profit losses in the EEA			
Anodising	CT	180	€1,578 million to €1,640 million
Chemical Conversion coating[2]	CT, SD, PD, DtC	350	€5,942 million to €14,172 million
Electroplating	CT	125	€1,336 million to €4,392 million
Passivation of stainless steel	CT, SD	70	€790 million to €2,720 million
Profit losses in the UK			
Anodising	CT	30	€247 million to €623 million
Chemical Conversion coating[1]	CT, SD, PD, DtC	80	€950 million to €5,643 million
Electroplating	CT	25	€342 million to €1,381 million
Passivation of stainless steel	CT, SD	20	€239 million to €430 million

Notes:
1) CT = chromium trioxide, SD = sodium dichromate, PD = potassium dichromate, DtC = dichromium tris(chromate)
2) Mixtures containing DtC are not covered by this formulation review report and, hence, the full value of the profit losses given here would not be attributable to

As noted in the AoA-SEA documents supporting the surface treatment uses, relocation is economically unattractive even if it is the most plausible result for OEMs and other A&D companies. This is because: the due diligence principle would continue to apply to supply chains but would be exacerbated in case of relocation out of EEA; when activities are shifted to another site, there is an inevitable phase of technical and industrial qualification together with an assessment of technical capability to adhere to certification requirements; and once the qualification phase is over, it would be essential to get the right ramp up in order to meet manufacturing rate objectives.

Undertaking such activities would require huge economic investments that would significantly affect businesses and have severe detrimental economic impacts. As a result, companies would likely be forced to cease some manufacturing activities until new industrial facilities and infrastructure are in place and ready to operate outside of the EEA.

Particular difficulties would be faced by companies in the space and defence sectors. Possibilities for relocating some activities outside the EEA are limited due to the difficulties related to achieving specific customer requirements, national security considerations, work share agreements, and financial restrictions. As a result, it is likely that there would need to be requests for "defence exemptions" so that those activities that contractually must be maintained in their current location could continue within the EEA. It would also have implications for the manufacture of hardware for the European space industry, damaging its ability to remain independent.

5.2.4 Economic impacts on competitors

There would be few economic benefits for competitors to the current formulators (some of which are extensively involved in R&D with A&D companies) under the non-use scenario. The key constraints to the adoption of alternatives – whether alternative formulations, substances or techniques – are multi-fold and stem from the need for A&D companies to ensure that there is no reduction in performance from the adoption of an alternative. Alternatives must meet the strict performance requirements delivered by the chromates in the manufacture, maintenance, repair and overhaul of components and end products. As a result, A&D companies cannot adopt an alternative until it has gone through full R&D testing and development, been qualified, validated and certified.

Even then, an alternative must be implemented (i.e. industrialised) through the supply chain before competitors would realise any benefits under the non-use scenario. Such benefits would only be realised if the A&D industry did not relocate the chromate-using surface treatments to other regions where the current formulations could continue to be used.

As a result, there no significant bringing forward of the use of alternatives compared to the continued use scenario is likely, leading to no significant economic benefits for suppliers of alternatives to the Cr(VI)-based mixtures.

5.3 Social impacts

5.3.1 Introduction

The primary social impacts considered here are the job losses that would result from a cessation of the manufacture of the mixtures used by the A&D industry in Europe. The scale of these associated with the loss of formulation specific to the production of mixtures for the A&D industry alone are likely to be small, but if taken together with the non-authorisation of formulation for other uses of the chromates would become significant.

This is discussed further below as part of the assessment of social impacts.

5.3.2 Monetary valuation of job losses

The Dubourg (2016) social cost methodology was used to calculate the estimated social costs of unemployment as recommend by ECHA.[36] Costs of unemployment are calculated by adding up lost output which is equivalent to the pre-displacement gross salary throughout the period out of work, search costs, rehiring costs for employers and scarring effects, and deducting the value of leisure time.

[36] Dubourg, R., (2016), Valuing the social costs of job losses in applications for authorisation, available at: https://echa.europa.eu/documents/10162/13555/unemployment_report_en.pdf/e0e5b4c2-66e9- 4bb8-b125-29a460720554, accessed September 2022

Dubourg (2016) estimated the ratio of the social cost per job loss over the annual pre-displacement wage for European countries was found to be 2.72 as an average for the EU-28 and 2014; the UK specific ratio was found to be 2.09.

This figure is used here to protect commercially sensitive data on the number of jobs that would be lost across the formulators covered by this SEA (four in the EEA and two in the UK). It is combined with data on annual wages to calculate the social costs per lost job. The typical range for employees involved in formulation activities is from €30k to €75k for formulation, with a figure of €40k adopted here for the EEA and applied across all locations and job losses.

A similar figure (£35k) is applied in the UK, based on the relevant wage range of between £25k and £85k and an assumed weighting towards the lower end of this range.

5.3.3 Calculation of direct job losses across the EEA

Job losses would arise not just for those workers directly involved in formulation activities, but also workers involved in administrative roles associated with account management, distribution etc. of the final mixtures. As some of these roles may also be linked to other downstream uses, losses include those that would equate to less than a full time equivalent across the different sites.

The resulting estimates of the social costs of unemployment are given in **Table 5-3**. In total, around 120 jobs would be lost across the four EEA sites involved in formulation, with the social costs of unemployment linked to formulation of mixtures for the A&D sector alone equating to around €13.4 million over the first two years after a refused Authorisation.

The formulators in the EEA produce Cr(VI) mixtures for use by other sectors. If formulation for use in those sectors was also refused re-authorisation, then workers would be unable to shift from their work related to A&D products to activities linked to products manufactured and sold for use by other sectors. This may mean that the impacts presented in Table 5-3 are an underestimate of impacts in such a scenario.

Table 5-3: Job losses expressed as social costs of unemployment in the EEA

Chromate	Job losses	Social cost ratio	Average gross salary (€)	Social costs of unemployment (€)
Chromium trioxide	65	2.72	€ 40,000	€ 7,072,000
Sodium dichromate	25	2.72	€ 40,000	€ 2,720,000
Potassium dichromate	18	2.72	€ 40,000	€ 1,958,400
Sodium chromate	15	2.72	€ 40,000	€ 1,632,000
Total	**123**	-		**€ 13,382,400**
Source: Study team analysis				

The level of job losses in the UK would be lower than in the EEA given the more restricted level of formulation activities that take place there. Across the two formulators, 10 full time equivalent jobs would be lost where this includes those directly involved in producing the formulations and those that would be affected in these companies indirectly through loss of marketing and other supporting administrative activities.

Based on a social costs of unemployment multiplier of 2.09, the social costs would equate to €836,000 (or £731,500).

5.3.4 Wider indirect and induced job losses

Jobs would also be lost in the EEA and UK due to the relocation of manufacturing and MRO activities within the A&D sector. The numbers of jobs lost could easily exceed 100,000 across companies involved in civil aeronautics, space, military and land and naval surface treatment activities, given that these activities account for over 880,000 jobs in total. This is especially the case given that OEMs have indicated that their most likely response to the non-use scenario is relocation of manufacturing activities outside the EEA/UK.

Indeed, data supplied by ADCR members and their suppliers involved in surface treatment activities indicates that over 71,000 jobs in the EEA and a further 12,800 in the UK would be lost if the mixtures used in chemical conversion coating alone were no longer available (selected as the treatment used at the highest number of sites). Clearly these figures would increase if the mixtures used in the other nine surface treatments were no longer available, given not all smaller suppliers will be involved in both chemical conversion coating and e.g. electroplating, or may employ most of their workers in activities other than chemical conversion coating.

The economic impacts of the indirect job losses would therefore be enormous. The indirect effects associated with the loss of chemical conversion coating mixtures, for example, would be around £6.88 billion for the EEA and over £0.86 billion for the UK.

Such losses in A&D jobs would also trigger further job losses. A UK Country Report on the “Economic Benefits from Air Transport in the UK” produced by Oxford Economics (2014) identifies the following multiplier effects for the A&D sector and its contribution to UK employment (in 2012):

- A multiplier effect of 1.36 indirect jobs for every direct job;
- An additional multiplier effect of 0.84 induced jobs for every direct job.

This implies that the total social costs of unemployment would be three times higher than the costs to the A&D sector alone and orders of magnitude higher than the social costs of unemployment linked to the direct job losses at formulation sites.

5.3.5 Summary of social impacts

To summarise, the social impacts that would arise under the non-use scenario include the following:

- Direct job losses: around 120 workers in the EEA involved in formulation and associated administrative activities linked to the mixtures used by the A&D sector; 10 workers involved in formulation and associated administrative activities in the UK linked to the mixtures used by the A&D sector. Note that these losses assume authorisation of A&D mixtures alone are not authorised;
- Social costs of unemployment: economic costs of around £11.52 million in the EEA due to direct job losses, with the figure for the UK being €836,000 (or around £731,000); and
- Indirect and induced unemployment at the regional and potentially national level for the A&D industry: impacts felt due to the relocation of surface treatment and manufacturing

activities, leading to tens of Euro billions in social costs in the EEA and billions of pounds Sterling in the UK.

5.4 Wider economic impacts

5.4.1 Production of new aircraft

As noted in Section 4.3.2, demand for passenger and cargo air traffic is expected to grow into the future. Airbus' Global Market Forecast for 2022-2041 predicts that passenger air traffic will grow at 3.6% CAGR and freight traffic will grow at 3.2% CAGR globally. As a result, by 2041, there will be some 46,900 aircraft in service, with this including an estimated 39,500 new passenger and freighter aircraft (and the retirement of some of the older aircraft. This includes delivery of new aircraft for the European market, as well as the Asian and Chinese markets.[37] Similarly, Boeing's 2022 Commercial Market Outlook[38] indicates that the global fleet will increase by around 80% through to 2041, with the forecast value of new airplane deliveries at around US $7.2 trillion (based on a slightly higher growth in traffic at around 3.8% CAGR).

Based on figures publicly available on Airbus' website, the demand for new aircraft will progressively shift from fleet growth to accelerated replacement of older, less fuel-efficient aircraft. This will mean a need for over 39,000 new passenger and freighter aircraft, delivered over the next 20 years; around 15,250 of these will be for replacement of older less fuel-efficient models. By 2040, the vast majority of commercial aircraft in operation will be of the latest generation.

Under the non-use scenario, EEA/UK based A&D companies would no longer play a major role in meeting this demand for new aircraft, leading to losses in their contribution to gross value added and gross domestic product. As noted in Section 4.3.2, the European aerospace sector is a global exporter of aircraft, and A&D products make a significant contribution to the overall balance of trade. However, unless operations in the EEA/UK can remain technically and financially viable in the short to medium term, the ability of EEA/UK based OEMs to carry out manufacturing at the levels implied by these compound annual growth rates is unlikely to be feasible. As a result, manufacture of the newer generations of aircraft and military products may shift to locations outside the EU/UK with a consequent loss in GVA to the EU and UK economies, with enormous impacts on employment.

Not only would the manufacture of new aircraft in the EEA and UK be impacted but anticipated growth in the aftermarket parts segment would also be affected. The aircraft spare components/final product market encompasses the market for both new and used rotable[39] components available as spares for aircraft and other products. This market was projected to grow with a CAGR of over 4% over the period from 2022-2027, although this rate may now be lower due

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37 https://www.airbus.com/sites/g/files/jlcbta136/files/2022-07/GMF-Presentation-2022-2041.pdf

38 https://www.boeing.com/commercial/market/commercial-market-outlook/index.page

39 A component which is removed and replaced at pre-determined intervals measured in elapsed flight hours and/or flight cycles after which the removed item is sent for overhaul and will be subsequently re-used.

to Covid-19. Growth is due to the increase in the commercial aircraft fleet as well as the need for timely MRO services to keep aircraft in-service.

The overall outcome would run contrary to the EU's New Industrial Strategy[40] which identifies the A&D sector is one of the 14 sectors important to innovation, competition and a strong and well-functioning single market.

5.4.2 Impacts on airlines

Under the non-use scenario, the unavailability of the Cr(VI) mixtures would have a significant impact on the ability of EEA/UK-based MROs to undertake repairs and to follow normal maintenance and overhaul schedules. MROs are legally bound to adhere to the requirements set out in OEMs' manuals to meet airworthiness and military safety requirements. Where maintenance or overhaul activities would require use of the Cr(VI) mixtures, these would now have to be performed outside the EEA/UK until the OEMs had gained approvals and certifications for use of alternatives and had adapted the manuals setting out maintenance, repair and overhaul instructions.

When an aircraft needs repairs (i.e., flightline or "on-wing" repairs), it will be grounded at an airport until these take place due to airworthiness constraints. This would result in Airplanes on the Ground (AOGs) and could result in an aircraft having to be towed outside the EEA for repairs, with dramatic financial and environmental impacts.

If MRO facilities relocate outside the EEA/UK, airlines may also experience additional delays to routine aircraft maintenance due to capacity constraints at MRO facilities located outside the EU. Indeed, it may take some time to build up capacity to accommodate additional demand from EU-based operators, potentially resulting in a large number of aircraft being grounded until maintenance checks can be completed.

As a result, airlines would need to have additional spare components/engines/planes to account for the added time that aircraft would be out of commission due to extended MRO times. Airports may also have to build up large inventories of spare components to replace hardware that currently can be repaired, with this going against the desire to ensure sustainability within the sector.

The need to have maintenance carried out outside the EEA/UK would also lead to additional operational costs being incurred through increased fuel use. Small planes (e.g., business jets) that do not have the fuel capacity or airworthiness approvals for long haul flights would need to make multiple stops enroute to non-EEA MRO facilities and back. The impacts for larger craft would also be significant. For example, flying from Western Europe to Turkey or Morocco adds approximately 3,000 km each way and for a Boeing 737 and would take slightly less than four hours. For an airline which has 50 aircraft requiring an annual "D check" (heavy maintenance inspection of most parts, carried out every 6-10 years), this would involve 400 hours of flight time (return trip) or 20 days of foregone revenue, equivalent to €1.4 million. Scaling this up to the EU passenger aircraft fleet, which stands at approximately 6,700, suggests lost revenues in the tens of millions per annum just due to the need for around 700 aircraft to have a "D check" each year. Using the above estimate for

[40] https://op.europa.eu/en/publication-detail/-/publication/52904a0b-ae95-11eb-9767-01aa75ed71a1/language-en

a fleet of 50 aircraft, this would amount to €20 million in revenue lost by European airlines for "D checks" alone.

On top of this will be the additional losses in revenues from not being able to transport passengers or cargo. For example, an Airbus A320 carries from 300 to 410 paying customers on one long-haul flight per day. If tickets cost on average €500 per customer; the revenue lost due to being 'out of action' for one day amounts to €175,000. In addition, the leasing costs alone of a plane being out of service is roughly $17,000 per day (based on a leasing cost for a large passenger jet of around $500,000/month).

As a result, the cost of extending the period over which a plane is out of service for repair or maintenance reasons may lead to significant new costs for airlines, delays for passengers and in the transport of cargo, as well as knock-on effects for GDP and jobs due to planes being out of service for longer.

As illustrated in Figure 5-1 below, the trend in air transport is for growth to occur at an average rate of over 4.0% per annum over the next 20 years. A similar growth is expected in air freight transport. If this growth path were to be achieved, by 2036 the air transport industry would contribute 15.5 million in direct jobs and $1.5 trillion of GDP to the world economy.

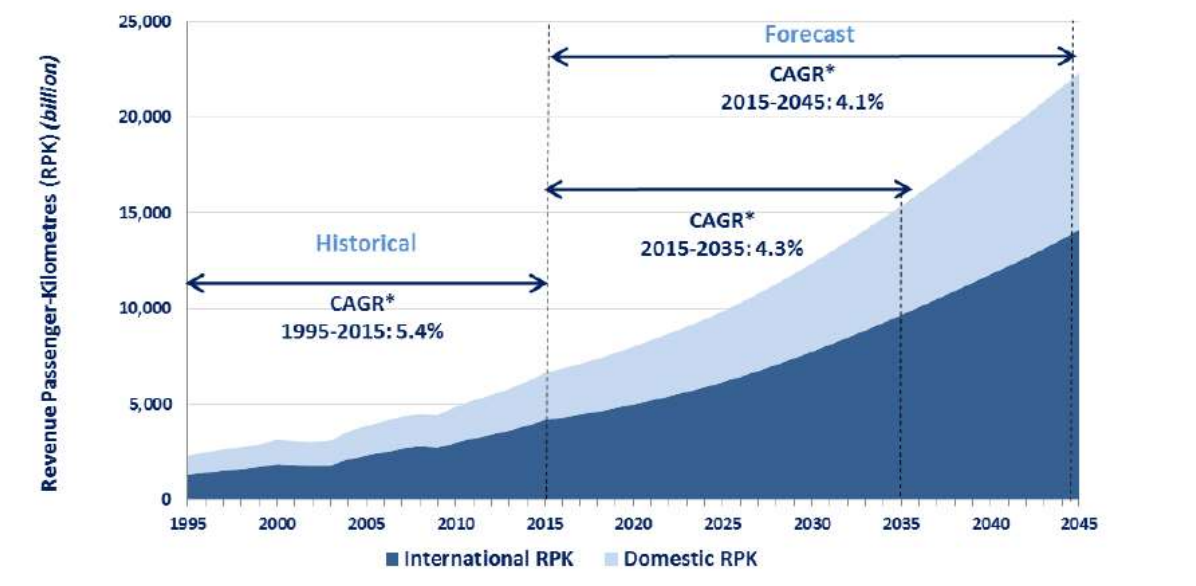

Figure 5–1: Forecast compound annual growth rates – Revenue Passenger-kilometres

The growth rate in Europe is expected to be lower at a compound annual growth rate of about 3.3% for total traffic[41] (covering inter-regional and intra-regional/domestic) for the period between 2018 to 2038. Achieving this level of growth in EU air traffic, together with the jobs and contributions to GDP that it would bring, would be impacted under the non-use scenario due to the inability of MROs to undertake repairs and carry out maintenance use the formulated Cr(VI).

[41] https://www.statista.com/statistics/1094689/annual-growth-rate-air-passenger-traffic-europe/

No quantitative estimate on the level of impact can be provided, but it is clear that the closure of EU-based MRO operations would impact on the availability of aircraft and, hence, passenger and freight transport until substitution has taken place in the manufacture of components and in their maintenance and repair (unless airlines responded by buying more planes or stockpiling of parts, which would inevitably give rise to increases due to the costs of holding spares and/or bringing spare planes on-line).

5.4.3 Defence related impacts

Defence related impacts under the non-use scenario would have two dimensions: impacts on airforces/military forces; and impacts on companies acting as suppliers to airforces/military forces.

Three national Ministries of Defence (MoDs – two in the EU and the UK MoD) have provided direct support to the ADCR out of concern over the impacts that non-Authorisation of the continued use of the chromates would have on their activities. In addition, MROs providing services to a further two MODs located in the EEA have supported the ADCR to ensure that they are able to continue to maintain and repair military aircraft, land and naval equipment into the future. The implications of having to cease these activities are significant. Aircraft (planes and helicopters) which could not be maintained to appropriate safety standards would have to be removed from service, with this also impacting on internal security services and emergency services. Not only would this impact on the availability of key equipment in the case of a military emergency, but it would also affect the size of potential operational forces and their "mission readiness".

It is also worth noting that Governments may be unwilling to send military aircraft to MRO facilities located in non-EU countries, although the US, Canada and Turkey are NATO members, and as such may be suitable candidates to service European military aircraft.

With respect to companies in the European defence sector, these represent a turnover of nearly Euro 100 billion and make a major contribution to the wider economy. The sector directly employs more than 500,000 people of which more than 50% are highly skilled. The industry also generates an estimated further 1.2 million jobs indirectly. In addition, investments in the defence sector have a significant economic multiplier effect in terms of creation of spin-offs and technology transfers to other sectors, as well as the creation of jobs. According to an external evaluation of the European Union's Seventh Framework Programme, through short-term leverage effect and long-term multiplier effects each €1 spent by the Seventh Framework Programme (FP7) generated approximately an additional €11 of estimated direct and indirect economic effects through innovations, new technologies and products.[42]

If the manufacture and servicing of military aircraft and other derivative defence products was to move out of the EEA/UK under the non-use scenario, as indicated by OEMs and the major Design-to-Build companies as the most likely response, then these multiplier effects would be lost to the EEA/UK economy. In addition, the ability of the EEA/UK to benefit from some innovations and technological advances ahead of other countries could be lost, if the shift in manufacturing remains permanent and extends to new products.

42 https://www.evropskyvyzkum.cz/cs/storage/bf5134fec407f6e005288c0e2631ad232c38c013?uid=bf5134fec407f6e005288c0e2631ad232c38c013

5.5 Combined assessment of impacts

Table 5-4 below provides a summary of the economic and social impacts arising under the non-use scenario.

Table 5-4: Summary of societal costs associated with the non-use scenario		
Description of major impacts	**Monetised / quantitatively assessed / qualitatively assessed impacts**	
Monetised impacts	**PV @ 4%, 2 years**	**€ annualised values**
Producer surplus losses to formulators due to non-authorisation of formulation using the four chromates	EEA formulators: > €7.5 million (£6.45 million) UK formulators: < €370,000 (£319,000)	EEA formulators: > €3.9 million (£3.4 million) UK formulators: < €200,000 (£170,000)
Producer surplus losses to A&D companies due to loss of mixtures based on the chromates	EEA A&D companies: not monetised but greater than €100 billion (£86 billion) UK A&D companies: not monetised but £ billions	EEA A&D companies: not monetised but € tens of billions UK A&D companies: not monetised but £ billions
Remediation / decommissioning costs	Not quantifiable as formulation for other sectors may continue	
Loss of residual value of capital	Not quantifiable as formulation for other sectors may continue	
Social cost of unemployment: workers in A&D sector only[2]	EEA jobs: approx. 120; UK jobs 10	
	EEA costs: €13.4 million (£11.5 million); UK costs: €836,000 (£731,500)	
Spill-over impact on surplus of alternative producers	Not assessed due to role that certification plays in the technical feasibility of alternatives to A&D customers of the formulators	
Sum of monetised impacts (job losses not annualised)	EEA: €20.9 million (£18 million) UK: €1.2 million (£1.05 million)	EEA: €17.3 million (£15 million) UK: €1.04 million (£901k)
Additional qualitatively assessed impacts		
Impacts on formulators	Impacts on R&D into alternatives, potentially broader mixture supply relationships with A&D companies	
Impacts on A&D sector	Impacts on R&D, manufacturing and MRO services carried out by the A&D sector, including lost profits, unemployment and an inability to service future growth in demand; impacts would affect the entire value chain	
Civilian airlines	Wider economic impacts on civil aviation, including loss of multiplier effects, impacts on airline operations, impacts on passengers and freight shippers, including flight cancellations, prices, etc.	
Ministries of Defence	Impacts on the operational availability of aircraft and military equipment, premature retirement of equipment, impacts on mission readiness	
GDP of EEA countries and UK	Impacts on the contribution of the A&D sector to GDP growth and employment into the future, as well as innovation and the adoption of new technologies	

6 Conclusions

6.1 Steps to identify potential alternatives and substitution plan

At the formulation stage, the chromates have no (separate) function, hence no analysis of alternatives can be provided. The functions played by the mixtures developed for use by the A&D sector are described in the review reports submitted for the ten surface treatment uses listed in Section 2.3 and Section 6.6.

These review reports foe each of the uses in surface treatment also identify the candidate alternatives and detail their current availability, taking into account their technical feasibility and economic feasibility and the need for alternatives to be qualified and certified for use in the manufacture, maintenance and repair of alternatives.

Substitution plans are also provided for each of the uses based on the R&D, testing, qualification and certification work currently underway by the major EEA and UK design owners, i.e. the OEMs and DtBs that set the performance requirements that must be met in order to ensure the airworthiness, safety and reliability of components and end products.

6.2 Comparison of the benefits and risks

6.2.1 Comparison between the benefits and risk

The requested review period for the continued use of the four chromates in formulation activities is 12 years for use in both the EEA and the UK. This requested period is linked to the longest period requested in review reports submitted to support the continued authorisation of the downstream surface treatments that rely on use of the mixtures produced by the relevant formulation activities.

Table 6-1 summarises the socio-economic benefits of continued use of the four chromates in the formulation of mixtures for use by the aerospace and defence sector. Overall, net benefits of between ca. €20.8 million (£17.89 million) for the EEA and €1.1 million (£0.95 million) for the UK can be estimated for the continued use scenario (Net Value social costs over 2 years/risks over 12 years, @4%). These figures do not include the economic value associated with the ability of downstream users in the A&D industry to continue manufacturing, maintaining and repairing A&D components and final products; nor do they account for the value to military forces of the continued availability of the Cr(VI) mixtures within scope of this review report.

These net present value estimates incorporate the monetised value of the residual risks to workers and humans via the environment estimated at €16,500 and €8,140 (£7,000) for the EEA and UK respectively over a 12 year period.

It should be recognised that the social costs of non-Authorisation would be much greater than the monetised values reported above, due to the severe direct consequences that this would have for downstream users in the A&D sector and military forces, and the follow-on effects for civil aviation, passengers, freight shippers, emergency services, tourism, etc.

Table 6-1: Summary of societal costs and residual risks			
Societal costs of non-use (2 years @4%)		**Risks of continued use (12 years @4%, 20 year lag in health effects)**	
Profit losses to applicants	Losses from reduced sales of the chromate substances and associated formulations: EEA: €7.5 million (£6.5 million) UK: €370k (£319k)	Health risks to workers at formulation sites	EEA: €15,747 (£13,542) UK: €7,486 (£6,453)
		Health risks to general population	EEA: €754 (£648) UK: €655 (£564)
Profit losses to A&D companies	EEA: £ tens of billions due to relocation UK: £ billions due to relocation *See other ADCR review reports*	Monetised excess risks to exposed A&D workers *See other ADCR review reports*	
Social costs of unemployment	Lost jobs EEA: 123 Lost jobs UK: 10		
	Social costs EEA: €13.4 million (£11.5 million) Social costs UK: €836,000 (£731,500)		
Qualitatively assessed impacts	Wider economic impacts on civil aviation, impacts on cargo and passengers. Impacts on armed forces including military mission readiness. Impacts on R&D and technical innovation. Impacts from increased CO_2 emissions due to MRO activities moving out of the EEA; premature redundancy of equipment leading to increased materials use.		
Summary of societal costs of non-use versus risks of continued use	- NPV (2 years societal costs/12 years residual health risks): ○ EEA: €20.8 million UK: €1.1 million (£945,000) - Ratio of annualised societal costs to residual health risks: ○ EEA: 1,260 to 1 UK: 136 to 1		

6.3 Information relevant to the duration of the review period

6.3.1 Introduction

In a 2013 document[43], the ECHA Committees outlined the criteria and considerations which could lead to a recommendation of a long review period (12 years):

1. The applicant's investment cycle is demonstrably very long (i.e., the production is capital intensive) making it technically and economically meaningful to substitute only when a major investment or refurbishment takes place.

[43] https://echa.europa.eu/documents/10162/13580/seac_rac_review_period_authorisation_en.pdf/c9010a99-0baf-4975-ba41-48c85ae64861

2. The costs of using the alternatives are very high and very unlikely to change in the next decade as technical progress (as demonstrated in the application) is unlikely to bring any change. For example, this could be the case where a substance is used in very low tonnages for an essential use and the costs for developing an alternative are not justified by the commercial value.

3. The applicant can demonstrate that research and development efforts already made, or just started, did not lead to the development of an alternative that could be available within the normal review period.

4. The possible alternatives would require specific legislative measures under the relevant legislative area in order to ensure safety of use (including acquiring the necessary certificates for using the alternative).

5. The remaining risks are low, and the socio-economic benefits are high, and there is clear evidence that this situation is not likely to change in the next decade.

Further discussion was held at the 25th Meeting of Competent Authorities for REACH and CLP (CARACAL) of 15 November 2017. A document endorsed by CARACAL suggests that, "*in order to consider a review period longer than 12 years, in addition to the criteria for a 12-year review period established in the document "Setting the review period when RAC and SEAC give opinions on an application for authorisation", two additional conditions should jointly be met*:

> *As evaluated by the RAC, the risk assessment for the use concerned should not contain any deficiencies or significant uncertainties related to the exposure to humans (directly or via the environment) or to the emissions to the environment that would have led the RAC to recommend additional conditions for the authorisation. In the case of applications for threshold substances, the appropriateness and effectiveness of the applied risk management measures and operational conditions should clearly demonstrate that risks are adequately controlled, and that the risk characterisation ratio is below the value of one. For applications for non-threshold substances, the applied risk management measures and operational conditions should be appropriate and effective in limiting the risks and it should be clearly demonstrated that the level of excess lifetime cancer risk is below $1x10^{-5}$ for workers and $1x10^{-6}$ for the general population. For substances for which the risk cannot be quantified, a review period longer than 12 years should normally not be considered, due to the uncertainties relating to the assessment of the risk.*
>
> *As evaluated by the SEAC, the analysis of alternatives and the third party consultation on alternatives should demonstrate without any significant uncertainties that there are no suitable alternatives for any of the utilisations under the scope of the use applied for and that it is highly unlikely that suitable alternatives will be available and can be implemented for the use concerned within a given period (that is longer than 12 years)"* (CARACAL, 2017).

As far as the second criterion above is concerned, the same document provides some relevant examples, one of which (Example (d)) reads as follows:

> "(…) *the use of the substance has been authorised in accordance with other EU legislation (e.g. marketing authorisation, certification, type-approval), the substance being specifically referred to in the authorisation/certification granted and substitution, including the time needed for modification of the authorisation/certification/type-approval, would not be feasible within 12*

years and would involve costs that would jeopardise the operations with regard to the use of the substance".

6.3.2 Criterion 1: Demonstrably Long Investment Cycle

The continued requirement for formulation using the chromates is driven by the stringent requirements placed on the A&D industry to ensure the airworthiness, safety and reliability of their products. These requirements are part of the reason for the long investment cycles within the industry, which in turn impact on the continued demand for use of the chromate mixtures in manufacturing, maintenance, repair and overhaul activities. The average lifespan of a civil aircraft is typically 20 to 35 years, while military products typically last from 40 to >90 years. Furthermore, the production of one type of aircraft or piece of equipment may span more than 50 years.

These long product lifespans and long investment cycles mean that it may not be feasible to carry out all of the tests required to qualify and certify a substitute, due to the level of investment and costs that would be involved in such an activity, as it would require testing at multiple levels (parts, sub-assemblies, assemblies, final aircraft/piece of equipment).

An aircraft is a complex system involving not only design of the device, but also its use and maintenance history in varied climates and service. Every single part needs to be designed and manufactured with serious attention and care. In such a complex system, change introduces new forms of failure. Any change will bring failures that can be anticipated but also some that are not anticipated. The parts in an aircraft or piece of military equipment need to be adjusted to each other very precisely at the manufacturing level, as well as the design level. As a result, very rarely is a substantial design change introduced into an existing product, as this would involve substantial cost and risk.

Even where small changes are considered feasible in principle, the implications are significant and highly complex; time consuming, systematic TRL-style implementation is required to minimise the impact of unanticipated failures and the serious repercussions they might cause. Even when an OEM has been able to undertake the required testing and is in the process of gaining qualifications and certifications of an alternative, whether a mixture, substance or technique, it may take up to seven years to roll out the use of a substitute across the industry due to the scale of the investment required and the need for OEMs to undertake their own qualification of different suppliers.

Ministries of Defence do not revise specifications for older equipment, which must nevertheless be maintained and repaired. MROs servicing military equipment therefore have to undertake any maintenance or repairs in line with the OEMs' original specifications, which means in line with any mixtures specified for use in maintenance or repairs. Similarly, MROs in the civil aviation field are only legally allowed to carry out maintenance and repairs in line with OEMs' requirements as set out in Maintenance Manuals. Long service lives therefore translate to on-going requirements for the use of the Cr(VI)-based mixtures in the production of spare parts and in the maintenance of those spare parts and the assemblies and aircraft/equipment they are used in.

As such, a review period of at least 12 years is warranted and requested for the continued use of the four chromates in formulation, given the highly complex systems that are dependent upon their use.

6.3.3 Criterion 2: Cost of moving to substitutes

Cr(VI) mixtures were validated/certified in the 1950s and 60s and extensive in-service experience has validated the performance of chromated materials. This includes modifications to design practice and material selection based upon resolution of issues noted in service.

Modern commercial aircraft in their entirety consist of between 500,000 to 6 million parts, depending on the model. Depending on the materials of construction, 15 to 70% of the entire structure of an aircraft requires treatment using Cr(VI) at some point during the manufacturing process. Older models generally require a larger percentage of Cr(VI) as the aerospace industry has worked diligently to incorporate new base materials and Cr(VI)-free protective coatings in newer models wherever it is safe to do so.

There are literally billions of flight hours' experience with parts protected from corrosion by formulated mixtures. On the other hand, there is still limited experience with Cr(VI)-free products on parts. It is mandatory that parts treated with a Cr(VI)-free alternative are demonstrably every bit as safe as they had been when treated with a Cr(VI) product. Flight safety is paramount and cannot be diminished in any way.

Where possible, and for specific parts and products, some new designs have been able to utilise newly developed alloys that do not require a Cr(VI) treatment (as typically used to provide corrosion protection on metallic legacy parts). However, even in newer designs there may still be a need for the use of Cr(VI) mixtures which cannot be replaced at present due to safety considerations.

6.3.4 Criterion 3 & 7: Results of R&D on alternatives and availability of alternatives over the longer term

Corrosion prevention systems are critical to aircraft safety. Testing in environmentally relevant conditions to assure performance necessarily requires long R&D cycles for alternative corrosion prevention systems. A key factor driving long timeframes for implementation of fully qualified alternatives by the aerospace and defence industry is the almost unique challenge of obtaining relevant long-term corrosion performance information on the alternatives. In some cases (e.g. CCC or passivation), it requires testing of changes in a system of corrosion protection, which includes changes in pre-treatments, main treatments and post-treatments.

A&D companies cannot apply a less effective corrosion protection system as aviation and defence substantiation procedures demand alternatives to be equal or better. If such performance is not achieved, then the alternatives cannot be used. The implications of changes in mixtures for repair, replacement and overhaul must also be understood before moving to an alternative. In particular, it must be recognised that the performance delivered by one part is dependent upon the performance of other parts; thus, the performance delivered by an assembly is dependent upon the sub-assemblies used and in turn the components used in the sub-assemblies. The number of configurations of component and sub-assemblies is immense and each configuration may differ from the next in terms of its behaviour with a Cr(VI) alternative.

6.3.5 Criterion 4: Legislative measures for alternatives

As discussed in detail in Section 3.1.2, the identification of a test candidate, Cr(VI)-free formulation is only the first stage of an extensive multi-phase substitution process leading to implementation of the alternative. This process, illustrated below, requires that all components, materials and processes incorporated into an A&D system must be qualified, validated, certified and industrialised before production can commence. Each phase must be undertaken to acquire the necessary certification to comply with airworthiness and other safety-driven requirements.

From start to finish, significantly more than 12 years is required to move from Phase 1 to Phase 5 (i.e. to identify, qualify, validate, certify and industrialise alternatives) for all critical A&D applications. The ADCR OEMs and DtBs – as design owners – are currently working through this process with the aim of implementing chromate-free alternatives by 2036; their current substitution plans are designed to ensure they achieve TRL9 and MRL10 within the next 12 years or sooner. This includes gaining airworthiness certification or military safety approvals, both of which can take up to several years to ensure safety. It may take more than 12 years to gain final approvals for some defence uses, particularly with respect to repairs, although the design owners are working to resolve current difficulties by 2036.

Several ADCR members note that most military procurement agencies require that all key components of defence equipment "shall be" produced within the European Union as a precondition. Thus, in contrast to other industry sectors, shifting production to a non-EU territory and import of finished surface treated parts or products into the EU is not a feasible option, as it would create a dependence on non-EU suppliers in a conflict situation.

They also note that the provision of defence exemptions, as allowed for in Article 2(3) of the REACH Regulation, is not a suitable instrument to ensure the continued availability of the chromates for CCC purposes if the renewal of the applicants' authorisations was not granted. While a national Ministry of Defence might issue a defence exemption out of its own interest, military equipment production processes may require the use of Cr(VI) mixtures by several actors in several EU Member States (i.e. it often relies on a transnational supply chain). In contrast, defence exemptions are valid at a national level and only for the issuing member state. Furthermore, the defence exemption process cannot be used as an alternative to the normal authorisation process unless this is necessary for confidentiality reasons and in the interest of defence. Thus, defence applications also need to be covered by the normal authorisation process.

Finally, the EU defence sector requires only small quantities of the four chromates for CCC. On the basis of a defence exemption alone, the quantities demanded would not be sufficient for manufacturers, formulators and surface treatment companies to continue to offer their services and products. As a result, CCC for military aircraft and equipment would not continue in the EEA or UK if other civilian applications were not also possible. This can only be ensured by the granting of an authorisation.

6.3.6 Criterion 5 & 6: Comparison of socio-economic benefits and risks to the environment and effective control of the remaining risks

The European aerospace and defence industry – including the formulators servicing it – is a world-class leader in technology and innovation. They are an essential part of the European economy contributing to job creation (880,000 direct jobs in 2020[44]) and Europe's trade balance (55% of products developed and built in the EEA are exported).

Civil aeronautics alone accounted for around €99.3 billion in revenues, with military aeronautics accounting for a further €47.4 billion in turnover; overall taking into account other defence and space turnover, the sector had revenues of around €230 billion. Of the €99.3 billion in civil aeronautics turnover, €88.3 billion represented exports from the EU.

Both acknowledged market reports of Airbus and Boeing find a growing trend in the aerospace industry. Airbus' Global Market Forecast for 2022-2041 predicts that passenger air traffic will grow at 3.6% CAGR and freight traffic will grow at 3.2% CAGR globally. By 2041, there will be some 46,900 aircraft in service, with this including an estimated 39,500 new passenger and freighter aircraft (and the retirement of some of the older aircraft. This includes delivery of new aircraft for the European market, as well as the Asian and Chinese markets in particular.[45] Boeing's 2022 Commercial Market Outlook[46] indicates a similar level of increase, noting that the global fleet will increase by around 80% through to 2041 with the forecast value of new airplane deliveries at around US $7.2 trillion (based on a slightly higher growth in traffic at around 3.8% CAGR.

As noted in Section 4.3, it is also expected that spending on defence equipment will increase in the future due to renewal of NATO members to meeting the target of spending 2% of GDP on defence. This increase in investment will equate to hundreds of billions of Euros (e.g. Germany alone has pledged €100 billion in defence spending) by EEA countries. Similarly, defence spending in the UK is expected to increase to over 2%, with projections in June 2022 suggesting 2.3% of GDP and Government commitments announced in October 2022 aiming for a target of 3% of GDP by 2030[47]. This equates to an increase in spending of around £157 billion between 2022 and 2030.

The socio-economic benefits of the continued use of the chromates in formulation, enabling the key manufacturing base of the EEA aerospace and defence industry to be maintained, are clearly significant; they will be the major beneficiaries of the growth in demand for civil aviation products as well as defence equipment.

6.4 Links to other Authorisation activities under REACH

This review report is one of a series of applications for the re-authorisation of the use of the Cr(VI) substances in surface treatments carried out by the A&D industry. This series of review reports has adopted a narrower definition of uses originally Authorised under the CTAC, CCST and GCCA parent applications for authorisation.

In total, the ADCR will be submitting 11 Review reports, including this one, covering the following surface treatment related uses of chromium trioxide, sodium dichromate, potassium dichromate, sodium chromate and dichromium tris(chromate):

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[44] https://asd-europe.org/sites/default/files/atoms/files/ASD_Facts%26Figures_2021_.pdf
[45] https://www.airbus.com/sites/g/files/jlcbta136/files/2022-07/GMF-Presentation-2022-2041.pdf
[46] https://www.boeing.com/commercial/market/commercial-market-outlook/index.page
[47] https://www.bloomberg.com/news/articles/2022-09-25/defence-spending-to-increase-by-at-least-52bn-in-response-to-russian-aggression or https://rusi.org/explore-our-research/publications/occasional-papers/famine-feast-implications-3-uk-defence-budget

1) Formulation
2) Pre-treatments
3) Electroplating (hard chrome plating)
4) Passivation of stainless steel
5) Anodising
6) Chemical conversion coating
7) Anodise sealing
8) Passivation of non-Al metallic coatings
9) Inorganic finish stripping
10) Chromate rinsing after phosphating
11) Slurry coatings