BEST PRACTICES GUIDE FOR

A Greener Aerospace Supply Chain

An initiative of the Canadian aerospace industry for green supply chain management.

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GARDN Green Aviation Research & Development Network

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CIRAIG™
International Reference Centre for the Life Cycle of Products, Processes and Services

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ABBREVIATIONS AND ACRONYMS

AFRA	Aircraft Fleet Recycling Association
AIAG	Automotive Industry Action Group
AM	Additive manufacturing
ASI	Aluminum Stewardship Initiative
BOM	Bill of material
CEPA	Canadian Environmental Protection Act
CIPEC	Canadian Industry Partnership for Energy Conservation
CO_2	Carbon dioxide
CSCL	Chemical Substance Control Law
CSR	Corporate social responsibility
DFE	Design for the Environment
ECHA	European Chemicals Agency
EEA	European Economic Area
EMAS	Eco-Management and Audit Scheme
EMS	Environmental management system
EPA	Environmental Protection Agency (U.S.A.)
EPD	Environmental product declaration
EPEAT	Electronic Product Environmental Assessment Tool
EU	European Union
GARDN	Green Aviation Research & Development Network
GHG	Greenhouse gas
GRI	Global Reporting Initiative
GSCM	Green supply chain management
HPD	Health Product Declaration
HPDC	Health Product Declaration Collaborative
HSE	Health & safety, environment
HSPM	Hazardous Substances Process Management
IAEG	International Aerospace Environmental Group
ICAO	International Civil Aviation Organization
ICMM	International Council on Mining & Metals
IMA	Integrated modular avionics
IRMA	Initiative for Responsible Mining Assurance
ISO	International Organization for Standardization
LCA	Life cycle assessment
LRU	Line replaceable unit
MQL	Minimum quantity lubrication
OEM	Original equipment manufacturer
ODS	Ozone-depleting substance
OTS	Off-the-shelf
PDCA	Plan-do-check-act
PESTLE	Political, economic, social, technological, legal and environmental
POP	Persistent organic pollutant
RACI	Responsible, Accountable, Consulted or Informed
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RFP	Request for proposal
ROHS	Restriction of Hazardous Substances Directive
SVHC	Substance of very high concern
TSCA	Toxic Substances Control Act
TSM	Towards Sustainable Mining
WEEE	Waste Electric and Electronic Equipment Directive

FOREWORD:
GARDN'S GREENING THE AEROSPACE SUPPLY CHAIN PROJECT

This guide is the main deliverable of the Greening the Aerospace Supply Chain project funded by the Green Aviation Research & Development Network's second program (GARDN II). The project aimed to provide OEMs and tier one suppliers with the knowledge and capacity to 1) prioritize their green purchasing actions; 2) define green specifications for materials and technologies; 3) efficiently collect, manage and assess environmental information in their supply chain; and 4) enable two-way communication and collaboration with suppliers to facilitate ecodesign throughout the supply chain. Research partners included Bombardier, Bell, Pratt & Whitney Canada, Groupe AGÉCO and CIRAIG (Polytechnique Montréal). The project was also supported by the Canadian Manufacturers & Exporters. The brochure produced during the project, the GSCM Business Guide, can be used as a GSCM promotional tool for suppliers. Both the Best Practices Guide and the Business Guide can be found at gardn.org.

01 Introduction

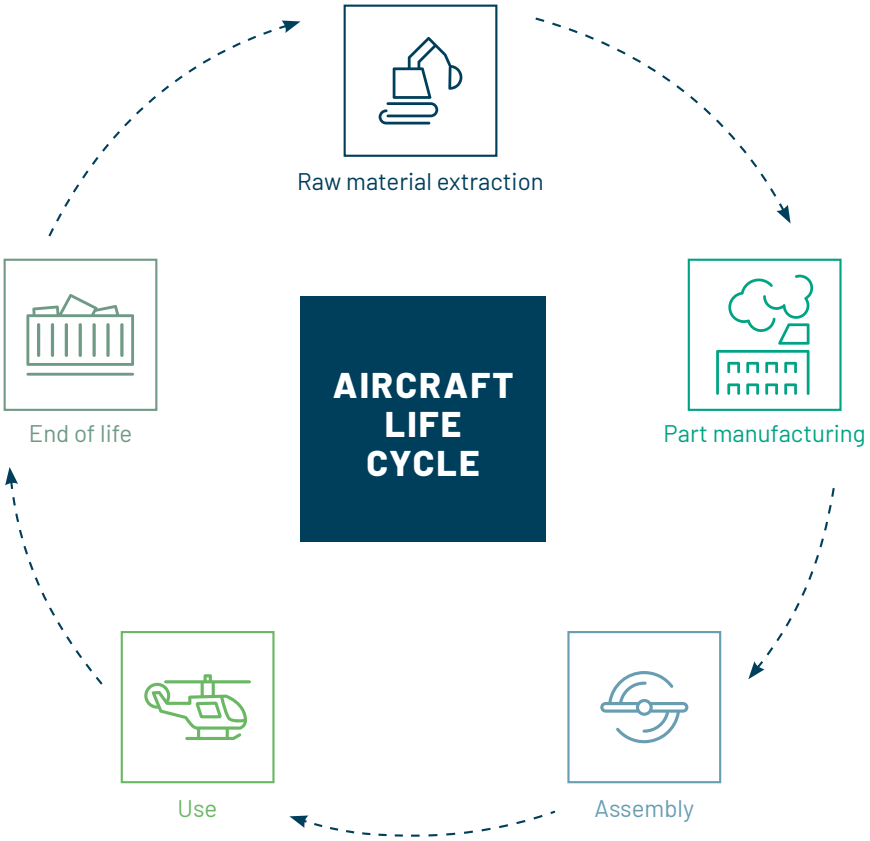
The aerospace industry is under pressure to reduce its environmental footprint: stringent CO_2 emission standards for civil air transport adopted by the International Civil Aviation Organization (ICAO) and strict regulations for chemical use in the European Union are among the most important drivers. The new regulations have led to corporate initiatives aiming to improve the situation. To take efficient action, the aerospace industry is working to assess and manage the environmental footprint of its operations and throughout its supply chain.

Many processes involved in manufacturing an aircraft have an impact on the environmental footprint of the products. When aiming to consider the environmental impacts generated throughout a product's life cycle, it becomes imperative to address impacts at the production site and in the supply chain. Consequently, it is critical to develop and adopt a green supply chain management (GSCM) approach.

Since the aerospace supply chain can be complex, globalized and multi-tiered, collaboration from all members of the aerospace sector is required. To fill this gap, GARDN, the Green Aviation Research and Development Network, spearheaded the Greening the Aerospace Supply Chain project. Its **objective is to reduce the overall environmental impact of the industry by promoting the adoption of green sourcing and green design practices with a GSCM framework.** This guide provides OEMs and their suppliers information on what GSCM is, why and how they should implement it, best practices and an overview of the environmental laws and regulations that could affect the aerospace supply chain. Finally, it offers useful green sourcing and design specifications for three key supply chain clusters: standard parts, avionics and composites.

Green supply chain management (GSCM): integration of environmental thinking into supply chain management to reduce the environmental impacts of a product during its life cycle.

02 Definition of green supply chain management (GSCM)



Aircraft impact the environment throughout their life cycle: during raw material extraction, part manufacturing, assembly, use and end of life. GSCM focuses on life cycle stages before and after the use stage by integrating ecodesign and environmental thinking into supply chain management "to eliminate or minimize waste of resources (energy and materials) and negative environmental impacts (air, water, and land pollution) through all phases of a product's life cycle."[1] This guide, intended for the aerospace sector, concentrates on raw material suppliers, part suppliers and the end of life.

1 Diabat A, Khodaverdi R, Olfat L (2013) An exploration of green supply chain practices and performances in an automotive industry. *Int J Adv Manuf* Technol 68:949–961. doi: 10.1007/s00170-013-4955-4

THE THREE PILLARS OF GSCM

GREEN SOURCING
Purchase environmentally responsible materials and parts

GREEN DESIGN
Include environmental criteria in product design

GREEN MANUFACTURING
Reduce resources/energy/material consumption, pollution and waste

Manufacturers practising GSCM can also have an influence on the use stage of their products, an environmentally important life cycle stage for aircraft, although not the focus of GSCM.

This best practices guide shows how aerospace manufacturers can influence their supply chain to reduce its product's environmental impacts. The practices presented herein cover the three key components at the core of a GSCM. approach: green sourcing, green design and green manufacturing.

03

The rationale behind GSCM

Implementing a GSCM approach in an organization not only generates environmental benefits, but also potential business gains since it reduces risks regarding reputation and environmental compliance. Further, an ISO 14001-compliant Environmental Management System (EMS) is an important lever for implementing GSCM since they are naturally aligned. The newest version of ISO 14001, an EMS standard, has integrated the life cycle perspective, which is central to the GSCM approach. Adopting a life cycle perspective is beneficial because it informs decision-making based on a system-level review of the environmental impacts and risks, and identifies where and when they occur. Concrete and tangible actions can then be adopted to mitigate them.

While responding to stakeholder needs, reducing costs and gaining a competitive advantage, GSCM also contributes to building an organization's readiness and resilience in the area of risk management. So GSCM offers the opportunity to improve both the environmental footprint and business performance, a win-win situation. Table 1 presents some of the mitigatable risks and newly discovered opportunities when using GSCM.

TABLE 1: RISKS AND OPPORTUNITIES IN THE AEROSPACE SECTOR

 INCREASE IN ENVIRONMENTAL REGULATIONS	 COST SAVINGS	 REPUTATIONAL RISKS
The rise of environmental regulations, such as REACH, is a major issue for aerospace and is constantly pushing organizations from the aerospace sector to rethink their processes and technologies. Organizations operating worldwide also often face discrepancies between international regulations. Heavy penalties for non-compliance and market access are both serious incentives for organizations to adopt GSCM, as well as to influence their own suppliers to adopt more responsible practices.	The supply chain in the aerospace industry presents multiple challenges such as resource availability, resource traceability, fluctuations in price and conflict-mineral sourcing. Implementing GSCM provides a solid structure for organizations to adopt and formalize responsible procurement practices, and ultimately address these challenges. In a continuous-improvement perspective, GSCM also presents huge potential for operations and production cost reduction.	In the last few years, we have seen that reputational risk can have a significant impact on an organization's financial performance (Sony, Volkswagen, BP, etc.). The practices of suppliers or partners throughout the value chain can also seriously affect an organization's reputation. Implementing GSCM allows organizations to forge collaborative relationships with suppliers and contributes to managing reputational risk across the supply chain. In this era of transparency, in which information is readily available, a company can no longer ignore its suppliers' practices. A company is increasingly held accountable for how it manages the hotspots in its supply chain.
Based on a survey on the state of green practices, products, processes, technologies and innovations in the Canadian aerospace industry conducted by Groupe AGÉCO and GARDN in 2017, 58% of companies in the sector already manufacture products or use processes that are REACH compliant.	The survey also reported that 47% of companies in the Canadian aerospace sector consider operations and production cost reduction as a main driver for implementing GSCM initiatives.	Volkswagen's diesel scandal resulted in a loss of over $30 billion for the organization. To manage its reputational risk, the company announced an investment of $60 billion in battery cells, to push the electrification of all its 300 models by 2030 (https://money.cnn.com/2017/09/29/investing/volkswagen-diesel-cost-30-billion/index.html).

For a more comprehensive business case for GSCM, see GARDN's four-pager entitled *Business Guide to Green Supply Chain Management*.

04 Overview of environmental regulations affecting the aerospace industry

Image courtesy of Bell Helicopter Textron Canada Ltd

The rise of environmental regulations is one of the main reasons to implement GSCM, as it mitigates the risk of non-compliance. As Canadian aerospace operations can span all around the globe and its customers can be in different countries, a myriad of environmental laws apply to the companies' products or operations. The associated legal requirements are constantly changing, and all businesses should ensure they are monitoring the evolution of the laws and regulations they are required to comply with as part of GSCM.

The following regulations are considered to have the most impact in the aerospace supply chain and concern the use of hazardous substances:

Canadian Environmental Protection Act (CEPA): companies operating in Canada have a set of obligations regarding toxic substances and must ensure they declare any of these substances that may be imported, produced or released into the environment.

Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH): this European regulation restricts the use of substances of very high concern (SVHCs) in Europe. Moreover, chemical substances must be registered in order to be produced or imported.

Toxic Substances Control Act (TSCA): this U.S. act also requires the registration of imported and manufactured chemicals. Authorization is required for the use of unlisted substances.

These are not the only relevant regulations. Appendix A provides information on important international environmental laws and regulations that may impact aerospace businesses and their suppliers. Legislation and standards regarding fuel efficiency, air emissions or noise during aircraft operations, although environmentally significant over its life cycle, were not included in this document since these issues are not directly addressed by GSCM. More information is provided by the International Aerospace Environmental Group (IAEG).

05 Green sourcing

Green sourcing is about reducing the environmental impact of a supply chain by changing the way a business purchases goods and commodities. Basically, the company follows responsible purchasing criteria based on either the suppliers' environmental performance or practices, specifications on the product itself or how it is manufactured. Green sourcing does not generally involve a change in aircraft design. This section presents three approaches to green sourcing:

1 ~ Supplier approach

2 ~ Product approach

3 ~ Off-the-shelf purchase vs. custom purchase

These approaches are further detailed in the following subsections.

5.1 SUPPLIER APPROACH

A company can improve the environmental impact of its supply chain by selecting suppliers based on specific sustainability and environmental criteria. This can be done with a green purchasing policy that establishes the following requirements:

1 ~ Strict adherence to a "supplier code of conduct or policy" (see Example 1)

2 ~ Compliance with the highest environmental standards and best practices (see Example 2 and 3)

3 ~ Requirement to communicate accordingly to internationally recognized reporting framework (such as GRI) (See Example 4)

4 ~ Requirement to deploy an environmental management system (e.g. ISO 14001:2015 certified) (see Example 5)

The following sections present more details about some of the sustainability-based requirements that can be used to select suppliers.

TOOL: SUPPLY CHAIN SURVEY

To perform green sourcing based on suppliers' environmental performance or practices, data collection is required. In this regard, the IAEG has developed an Environmental Supply Chain Survey. In addition to general company information, it collects information about the supplier's code of conduct, sub-tier environmental performance management, environmental management systems, risk management, pollution reduction goals, GHG accounting, chemicals, ecodesign and best practices. The survey helps keep track of progress towards responsible practices and could serve as a basis for selecting suppliers. Moreover, by standardizing data collection, it makes it easier for suppliers to provide data to customers. There are other supplier data collection tools on the market that include a wide range of subjects, such as social responsibility and governance (see section 6.3.3).

EXAMPLE 1 - CODE OF CONDUCT

According to Ecovadis, a business sustainability rating provider, the purpose of a supplier code of conduct is to ensure that suppliers follow minimal social and environmental standards, covering subjects like labour practices and standards, environmental policy, ethics, and documentation policy. It clarifies the expectations of a company towards its suppliers. Codes of conduct are important when the supply chain is present in regions where environmental law or working conditions are not enforced. International standards are commonly used as a reference such as ISO 14000 and SA 8000. Monitoring supplier compliance with the best environmental and social practices is a very important aspect of a code of conduct.

A code of conduct can be created by assessing the risks in the supply chain, consulting suppliers and companies in the same industry, and examining other codes of conduct. Bombardier, for example, has its own supplier code of conduct.

~ Ecovadis's web page about supplier codes of conduct

~ Bombardier's supplier code of conduct

EXAMPLE 2 - HIGH ENVIRONMENTAL STANDARDS AND BEST PRACTICES: AN EXAMPLE FROM THE AUTOMOTIVE INDUSTRY

A code of conduct sets the minimum level for supplier qualification. A manufacturer could go a step further and use best environmental practices to select suppliers. For example, several automotive manufacturers in the Automotive Industry Action Group (AIAG) have elaborated green guiding principles that they expect suppliers to follow, which include:

Energy and GHGs: to implement an energy reduction strategy and increase renewable energy use.

Water: to reduce water use and improve the quality of discharged water.

Air quality: to monitor, control, minimize (or eliminate) air emissions contributing to local pollution.

Resource consumption and waste reduction: to encourage the use of sustainable resources, reduce waste, reuse and recycle.

Chemical substances: to identify restricted substances in product and processes, and reduce or eliminate their use.

These can serve as criteria to define best-in-class companies and to consider when selecting a product or a supplier.

~ Global Automotive Sustainability Practical Guidance by the AIAG

EXAMPLE 3 - HIGH ENVIRONMENTAL STANDARDS AND BEST PRACTICES: GHG INVENTORY

Another example of a good practice for a supplier is to calculate its GHG emissions. Companies measuring their emissions are already taking the first steps in the GHG-reduction process. The Paris Agreement, which came into effect in 2016, aims to keep the global temperature increase well below 2°C above pre-industrial levels. Therefore, GHG accounting is necessary.

According to the GHG Protocol, there are three scopes of accounting:

- **Scope 1**: the direct GHG emissions from the company (e.g. combustion emissions from heat production)
- **Scope 2**: the indirect emissions from electricity and heat production used by the company but not generated by it. In this scope, for example, GHG emissions from a coal power plant supplying electricity to the company are calculated.
- **Scope 3**: all other indirect emissions related to the company, such as from the production of purchased goods and services, fuel production, transportation, distribution, as well as product use and end of life.

The ISO 14064 standard is a more general framework for GHG accounting in organizations. The IAEG has developed supplemental GHG reporting guidance for the aerospace industry based on the GHG Protocol. One of its goals is to standardize the process in the industry. A particularly important requirement is to use the operational control approach to define an organization's boundaries, as opposed to financial control, and to calculate scopes 1 and 2 at the very least. It also gives provisions on including joint ventures, subsidiaries, remediation sites and on other aspects.

- GHG Reporting Guidance by the IAEG
- GHG Protocol

EXAMPLE 4 - COMMUNICATION OF ENVIRONMENTAL PERFORMANCE

More and more businesses declare their GHG emissions to reporting initiatives like the CDP (formerly known as the Carbon Disclosure Project). It shows investors that the company is managing GHG emissions transparently and credibly. But other environmental indicators can be communicated as well. The Global Reporting Initiative is a reporting framework for corporate social responsibility (CSR) and sustainability, which includes social, environmental and economic indicators. It helps an organization understand what its potential risks might be, to monitor them, build trust among stakeholders and improve performance. Publicly disclosed corporate performance and practices are compiled and rated by specialized firms like Sustainalytics and RobecoSAM. Such ratings can be used to select suppliers with the best performance.

- CDP
- Global Reporting Initiative
- Sustainalytics
- RobecoSAM

EXAMPLE 5 - ENVIRONMENTAL MANAGEMENT SYSTEM (EMS)

A company could request that its suppliers have an EMS, as is currently done by one major aircraft manufacturer. An EMS implements continuous improvement by mitigating significant environmental impacts. ISO 14001 is the main example of EMS standards. Europe also works with the Eco-Management and Audit Scheme (EMAS). The IAEG has produced a report on the transition to the new ISO 14001:2015, which includes GSCM.

- Transitioning to ISO 14001:2015 (IAEG)

5.2 PRODUCT APPROACH

Another approach to green sourcing is to include green product specifications in calls for tenders or contracts. Green product specifications address a characteristic of the product or the way it is manufactured. In practice, they are used in the procurement process to ensure that:

1 ~ The product is compliant with existing environmental regulations (e.g. hazardous substances);

2 ~ The product meets specific environmental performance levels; and

3 ~ The product meets specific recovery and/or end-of-life guidelines.

1 ~ COMPLIANCE WITH REGULATIONS

Section 4 described the many regulations that restrict chemical usage or waste treatment. Those regulations apply to specific countries or regions, or to other industries. However, some can serve as green product specifications for the aerospace industry outside the regulated area, such as the European Waste Electric and Electronic Equipment Directive Waste Electric and Electronic Equipment Directive (WEEE) for avionics. This regulation identifies the manufacturer and distributor of electric and electronic equipment (EEE) as responsible for collecting and managing their end-of-life disposal.

~ The WEEE Directive

2 ~ ENVIRONMENTAL PERFORMANCE

Environmental performance criteria can be used to select products with a lower intrinsic environmental footprint, but also to select products that were manufactured using a greener process.

EXAMPLES OF GREEN PRODUCT SPECIFICATIONS

The following specifications can apply to products:

~ Recycled material content

~ Free of hazardous substances (e.g. chromium-based paints, halon fire suppressants)

~ Recyclable

~ Certified or made with materials certified by a recognized environmental certification scheme (e.g. EPEAT, ASI, Responsible Steel, IRMA; see Appendix B for certifications applicable to standard parts, avionics and composites)

TOOLS
LIFE CYCLE ASSESSMENT (LCA) AND ENVIRONMENTAL PRODUCT DECLARATION (EPD)

Life cycle assessments (LCAs) quantify the environmental impacts of a product over its life cycle, from raw material extraction to manufacturing, use and end of life. They include several environmental indicators, such as the carbon footprint. With such a large scope, LCAs provide the most comprehensive information when comparing products based on environmental criteria and therefore help organizations make environmentally sound purchase decisions.

While LCAs often compare different products, an environmental product declaration (EPD) is a standardized LCA-based label for a single product. It is a summary of LCA findings presented in an internationally recognized format similar to nutritional facts. It makes it possible to compare the environmental performance of a new product with its previous version or with average industry results. Although most existing EPDs are for construction products because of green building certifications, they have been seen for aircraft as well.

In addition, life cycle assessment and the environmental product declaration are recognized tools that can be used to optimize and design more environmentally friendly products. As such, it could be a useful strategy to rely on the information they provide as you define green procurement specifications for your products, but also to compare options using a formal and an analytical method.

- Specifications of green goods and services from the Government of Canada
- EPA's Sustainable Marketplace
- ISO 20400:2017 on sustainable procurement

EXAMPLES OF GREEN MANUFACTURING PROCESS SPECIFICATIONS

Green specifications can also be applied in specific manufacturing processes. In this case, the objective is to define requirements aimed at reducing the overall environmental footprint of the manufacturing process.

The following list presents some example of green manufacturing processes:

- Near-net-shape forming: reduces forging size and scrap materials from machining
- Powder metallurgy and additive manufacturing: reduces material by forming metal objects from metal powder
- Renewable energy use in facilities
- Near-dry and minimum quantity lubrication (MQL) processes: avoids the use of large quantities of coolants and the treatment of coolant waste.

The use of an LCA is strongly recommended to identify manufacturing processes that are less harmful to the environment.

3 ~ RECOVERY AND END-OF-LIFE GUIDELINES

End-of-life management in the aerospace sector can be a challenging aspect and a significant source of environmental impacts. To better manage the end of life of the components and products being used and manufactured, developing clear and direct guidelines is considered a best practice.

A relevant source of information on this topic for the aerospace industry is provided by the Aircraft Fleet Recycling Association (AFRA), which has published the Best Management Practice for Management of Used Aircraft Parts and Assemblies and for Recycling of Aircraft Materials. This document gives provisions on aspects such as security, storage, transportation, training, tooling and processing. The relevance of such guidelines is not limited to decommissioned aircraft, but also applies to products in the manufacturing process. The International Air Transport Association (IATA) has also published a document on aircraft decommissioning, which provides the best practices at the end of life of commercial aircraft.

- AFRA Best Management Practice for Management of Used Aircraft Parts and Assemblies and for Recycling of Aircraft Materials (BMP)
- Best Industry Practices for Aircraft Decommissioning (BIPAD)

5.3 OFF-THE-SHELF PURCHASE VS. CUSTOM PURCHASE

Off-the-shelf (OTS) or standard items are purchased as they are sold to any other customer, while custom purchases imply that specific product characteristics be provided to the supplier, who manufactures the product accordingly.

OTS and custom parts have different advantages in terms of time, cost and performance. Many technical and business factors must be considered to select one type over another. Green specifications can apply to both part types, but the way they are applied may differ. For OTS parts, the customer can require green specification compliance from suppliers and select compliant products accordingly.

When OTS parts are not available with the desired green specification, the alternative may be to order it custom. In that case, a request for proposals would be prepared to define the specifications of the part, including the desired green specifications. This is also an alternative when the order volume does not provide sufficient leverage for a supplier to offer an OTS part with a green specification.

Since custom parts may increase costs, priority should be given to those that provide the greatest environmental benefits. An LCA identifies environmental hotspots in the supply chain and provides quantitative data that can be used to determine which parts should be made custom.

~ Green Procurement for Congress (U.S.A.)

TOOLS

GREEN SOURCING AND DESIGN FACTSHEETS ON STANDARD PARTS, AVIONICS AND COMPOSITES

During the GARDN GSCM project, three areas of the aerospace supply chain, or clusters, were analyzed in more detail: **standard parts, avionics and composites.** The analysis used life cycle assessment (LCA), the best tool to identify environmental hotspots in the supply chain along the product life cycle. The goal was to formulate specific green sourcing and design recommendations for the three clusters identified as important. Three fact sheets present the results and recommendations for each cluster. (See Appendix B)

06 Green design

Also known as Design for the Environment (DfE), this GSCM strategy revolves around modifying the product design to reduce its environmental impact. Depending on the design, such reductions are possible throughout the entire product life cycle (raw material acquisition, part manufacturing, assembly, use and end of life).

Green design strategies may include the following measures (which are presented in more detail below):

1 ~ Selection of conflict-free minerals

2 ~ Selection of non-hazardous materials

3 ~ Use of LCA and life cycle-based metrics

4 ~ Design for material circularity

5 ~ Design for additive manufacturing and raw material demand reduction

~ ISO 14006 Guidelines for incorporating ecodesign

~ The Designer's Field Guide to Sustainability

Note that green design is a vast subject and this section only provides an introduction. The reader is invited to refer to the proposed links throughout the section for more information.

6.1 SELECTION OF CONFLICT-FREE MINERALS

The term "conflict-free minerals" is associated with the use of minerals that are not extracted from conflict areas where the trade of such minerals would benefit armed groups. As reported in section 4, some minerals and metals such as tin, tantalum, tungsten and gold are likely to come from conflict areas, where stringent environmental laws are not likely to exist or be enforced. The EU has adopted a law to stop the importation of such minerals into its territory, largely due to the social consequences of trading these resources from such regions. Moreover, in the U.S.A., the *Dodd-Frank* Act and related U.S. Securities and Exchange Commission rules require certain companies to disclose the use of conflict metals from the Democratic Republic of Congo and other countries in the Great Lakes region of Africa. Based on these regulations, a minimum criterion for a conflict-free mineral could be that it must not come from these regions.

In addition, a recent report for the automotive and electronic industries entitled *Material Change* analyzed 37 materials contained in cars and smartphones based on their use and their association with several environmental, social and governance risks. This report can serve as a reference to assess material use and the risk they represent in the supply chain. For example, tantalum, gold, tin and cobalt are strongly associated with countries with weak rule of law, incidences of overlap with important conservation areas and the potential of acid leaks into the environment. Each of these materials is profiled in the report so that the most responsible sourcing countries can be identified. However, as a manufacturer, it may be difficult to know the origin of the raw materials that are purchased. Consequently, the Responsible Minerals Initiative provides information about systems and processes that support conflict-free sourcing of raw materials at the smelter and refinery levels.

~ Conflict Minerals Regulation in the European Union

~ U.S. Department of State and conflict minerals

~ Material Change, a report about conflict minerals in the automotive and electronics industries

~ Electronic Components Industry Association

~ Responsible Minerals Initiative

6.2 SELECTION OF NON-HAZARDOUS MATERIALS

Because of the implications of design changes on airworthiness certification and the lengthy service life of aircraft requiring decade-long stability in part production, the phasing out of hazardous substances in design is a challenge in aerospace. However, design changes may be necessary to adapt to non-hazardous alternatives that may not be equivalent in terms of technical properties and behaviour. The IAEG has produced tools and documentation about the REACH and the TSCA regulations that restrict the use of hazardous substances.

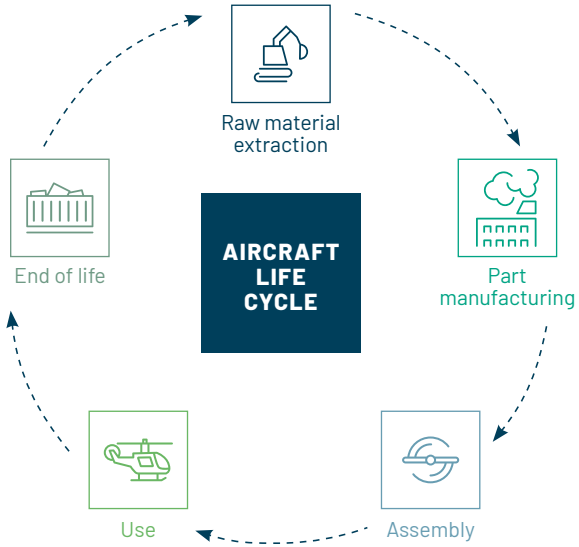
~ IAEG presentation about REACH

~ IAEG material on TSCA

~ RoHS Guide

6.3 LCA AND LIFE CYCLE-BASED METRICS

An LCA is a tool to advance sustainability practices. It is often touted as an important and robust way to ensure correct data is being incorporated into the **decision-making process, including green design or ecodesign.**



Its purpose is to ensure **more sustainable value chain management.** It can be used to target, organize, analyze and manage product-related information and activities towards continuous improvement along the life cycle.

An LCA's broad scope ensures that tangible improvements are made as it measures effects across the life cycle so as to **prevent the shifting of burdens** to other types of environmental impacts and/or other stages of the life cycle.

Green design with LCA can be done in different ways. Early in the design process, it can be used to compare the estimated environmental impacts of different design concepts so environmental metrics can be taken into account if the concept is selected for further development. When the design is mature, an LCA can identify its environmental hotspots, i.e. the life cycle stages where most of the environmental impacts occur. Based on that information, the design may be modified to reduce the impacts related to the identified hotspots.

~ Five Steps to Eco Design by Granta

6.4 DESIGN FOR MATERIAL CIRCULARITY

The circular economy brings together many concepts that aim to switch from a linear economy, i.e. which consumes virgin resources and transforms them ultimately into waste, to a circular one where all materials go back into the economy and waste is non-existent. At the product level, material circularity requires a very efficient use of materials. It does not rely solely on recycling, but also on reduced use of virgin materials and increased product utility. Therefore, the following measures contribute to increased material circularity:

- Lower buy-to-fly ratio
- Higher recycled content
- Higher recyclability and reuse possibilities
- Longer lifetime

There are many obstacles to including recycled content in new aircraft parts. Materials with limited or very specific functions are difficult to recycle. Also, when materials used in aerospace are recycled in another sector, they may downgrade in quality, which could prevent them from being returned to the aerospace supply chain. Therefore, keeping materials within the aerospace sector, e.g. by selling production waste back to your own suppliers or within your own plant, may help increase material circularity.

- Circularity Indicators by the Ellen MacArthur Foundation

6.5 DESIGN FOR ADDITIVE MANUFACTURING AND RAW MATERIAL DEMAND REDUCTION

This recent fabrication method, also known as 3D printing, consists of adding material layer by layer to obtain a final form instead of removing material from a block. This can be done with metal or composite materials. Complex parts can be achieved with this technique, which can reduce the material needed for equivalent performance. Therefore, material needs can be avoided by design. In the aerospace context, this weight reduction also leads to fuel economy during aircraft use. Studies have estimated that AM can not only reduce material consumption by design, but can also reduce manufacturing waste. For aircraft, conventional part manufacturing can exhibit a buy-to-fly ratio (mass of raw material needed per unit mass of the finished component) from 2:1 to as high as 33:1. AM can reduce this ratio to close to one.

- 3D opportunity for the automotive industry by Deloitte

07 Green manufacturing

Reducing the environmental impacts of plant operations is another step towards reducing a product's environmental footprint. It is part of the GSCM approach as measures taken at the factory to mitigate the environmental impacts of operations, e.g. to reduce energy consumption or waste, and to have beneficial consequences on the supply chain's environmental footprint. Moreover, it is the core of many companies' sustainability plan. The following list presents some examples of green operations strategies and actions:

Process quality
Improve yield, reducing scrap, save cost

Lean manufacturing
Improve resource efficiency, just-in-time supply chain

Energy

- Increase energy efficiency (e.g. use more efficient lighting, shut off unused tools/equipment)
- Actively minimize peak energy demand
- Adopt renewable energy sources at facilities
- Minimize the use of compressed air (e.g. use electric hand tools instead of pneumatic ones, reduce leaks)
- Optimize utilization / batch processing of high energy production equipment (e.g. heat treatment furnaces)

Water

- Implement closed loop processes and water recycling
- Reduce wastewater

Waste and material circularity

- Increase production waste recycling (e.g. reduce waste contamination, avoid dissipative use)
- Minimize contamination of high value scrap material and revert
- Minimize hazardous substances in manufacturing
- Recyclable packaging

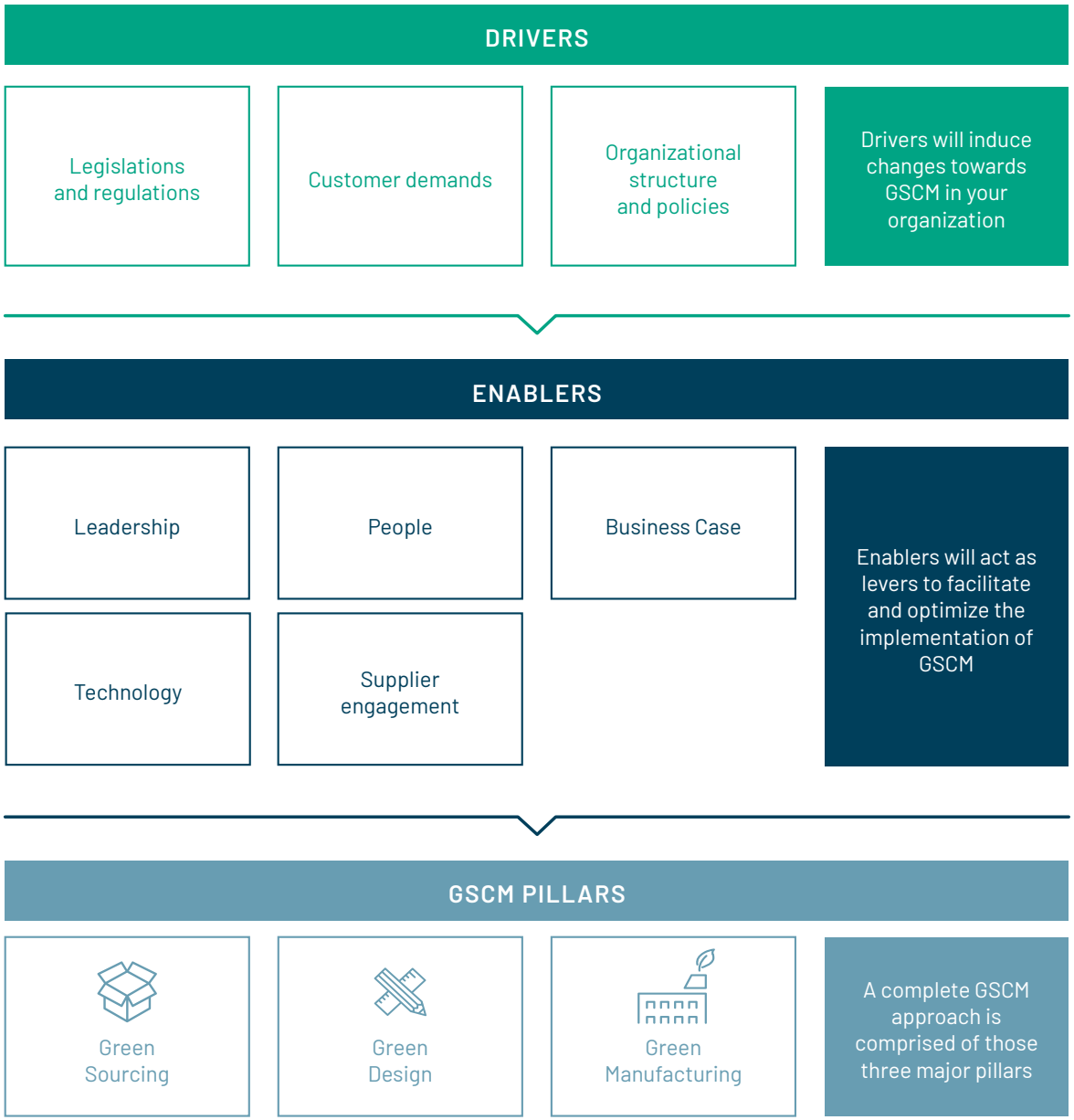
Hazardous substances
Minimize use in manufacturing processes

08 GSCM implementation

Many factors contribute to the successful adoption of GSCM. GSCM drivers and enablers are essential for its implementation. Inspired by ISO 20400 and BS 8903, the following figure identifies a few of them. For more details about the key success factors for implementing GSCM, see GARDN's four-pager entitled *Business Guide to Green Supply Chain Management*.

This section presents the iterative Plan-Do-Check-Act framework that is well adapted for the implementation of GSCM. Then, recommendations and best practices for governance and communication related to GSCM are provided. The section ends with three operational guides, one for each GSCM pillar, intended for the stakeholders who will apply the GSCM principles.

DRIVERS AND ENABLERS RELEVANT TO GSCM



8.1 APPLYING THE PLAN-DO-CHECK-ACT FRAMEWORK TO GSCM

One reliable way to implement GSCM strategies is to adopt the plan-do-check-act (PDCA) framework. This iterative framework consists of testing the implementation of a measure with a small-scale pilot project and then improving it based on the results before its deployment on a larger scale.

THE PLAN-DO-CHECK-ACT (PDCA) FRAMEWORK

PLAN

To plan the implementation of a GSCM strategy, the first step is to **identify market demand for green products.** Customers' demand for a greener supply chain may be driven by regulations or industry standards, or their own corporate social responsibility (CSR) objectives. Understanding what clients are asking for in terms of green products and practices will help prioritize actions for GSCM implementation. Environmental regulations that could affect the supply chain also help identify GSCM priorities (see Appendix A). The IAEG recommends assessing its internal and external issues by using the political, economic, social, technological, legal and environmental analysis (PESTLE). This can serve to set the scope of the GSCM strategy and set targets, which should prioritize significant environmental issues over which the company has some control or influence (see the document "Transition to ISO 14001:2015" by the IAEG). Further analysis may be useful to identify relevant environmental hotspots, such as an **LCA.**

DO

Depending on the market demand for a greener supply chain and the assessment of internal and external issues, the company will act on sourcing, product design and/or manufacturing. The Do step is about implementing a pilot project to test the GSCM strategy.

CHECK

Once the pilot project is completed, the company must measure and assess the outcomes and compare the results to the set targets. If the project was not successful, the factors that contributed to its low performance must be identified.

ACT

Based on the assessment of the project performance, adjustments to the GSCM strategy are made. Then the strategy is deployed at a larger scale in the business. If the pilot project was not successful enough, a second pilot project may be a good option to make sure the adjustments are sufficient to successfully implement GSCM.

8.2 GOVERNANCE

Establishing the appropriate governance structure is essential to help organizations lead GSCM projects. GSCM can be very challenging to implement since it requires different departments within a company to work together, such as design, engineering, procurement, plant operations, after-sales service and so on.

The following section presents the main elements required to maintain strong governance for GSCM[2]:

- Set GSCM goals for the organization and its suppliers
- Establish internal roles and responsibilities for GSCM
- Collaborate with suppliers by establishing appropriate structures and processes
- Align GSCM resources, structures and processes across the organization
- Implement an environmental management system (EMS)

2 https://www.ey.com/Publication/vwLUAssets/EY-building-responsible-and-resilient-supply-chains/$FILE/EY-building-responsible-and-resilient-supply-chains.pdf

8.2.1 GSCM GOALS

GSCM goals should be based on a clear, shared vision of GSCM, supported by all functions and levels of the business. The goals should be incorporated into the global business strategy itself to facilitate the implementation of the GSCM practices. Sharing common GSCM goals with suppliers is a great way to ensure collaboration and involvement.

EXAMPLE 1 - TOYOTA'S LIFE CYCLE ZERO CO_2 EMISSIONS CHALLENGE

The Japanese automobile manufacturer has established a goal of not only zero CO_2 tailpipe emissions for its cars by 2050, but also zero CO_2 life cycle emissions. This means the car manufacturer aims to eliminate or compensate all the CO_2 emissions occurring in its supply chain, including during material and part manufacturing and vehicle assembly, disposal and recycling. This will require the company to develop low-carbon materials and to expand the use of recycling, which will involve Toyota's suppliers.

- Toyota Environment

EXAMPLE 2 - THALES UK'S HEALTH & SAFETY, ENVIRONMENT (HSE) OBJECTIVES

Thales UK has set the objective of assessing the HSE maturity of all its class A suppliers, as well as all its new suppliers. Moreover, all new buyers will be trained in HSE.

- Thales UK's Sustainable Procurement Guide 2017

8.2.2 ROLES AND RESPONSIBILITIES

Defining clear roles and responsibilities is imperative to all project management. Implementing strong governance is even more relevant in the context of GSCM, as incorporating the approach often requires adding new responsibilities to team members across the organization.

The RACI matrix is one of the most recognized frameworks to determine and assign the roles and responsibilities for each activity in a project. This framework enables employees to be more engaged as expectations are clearly defined. Other frameworks exist, and an important factor in choosing one is building on existing business practices.

~ Understanding Responsibility Assignment Matrix (RACI Matrix)

8.3 COMMUNICATION

Communication is crucial when advocating in the sector about the benefits and opportunities associated with GSCM. The following section presents the main elements related to communication in a GSCM perspective:

~ Communication of GSCM goals and reporting

~ Training

~ Data management

8.3.1 COMMUNICATION OF GSCM GOALS AND REPORTING

Top management plays a key role in supporting GSCM implementation. By communicating the GSCM goals and expectations, both internally and externally, senior management provides a clear and shared vision of GSCM, supported by all functions and levels of the business. Understanding the target audience (i.e. suppliers, employees, etc.) ensures that the communication is tailored to the audience's needs and provides a greater level of mobilization from those involved once the implementation phase has begun. Gathering feedback from suppliers on their vision of GSCM helps organizations remain aware of the evolution of environmental stakes and trends.

A great way to demonstrate commitment and accountability to GSCM is to provide a structured reporting of GSCM performance. Sharing information in an efficient and transparent manner is the key to a successful collaborative environment. Moreover, the disclosure of supply chain information beyond the sustainability reporting mechanism shows leadership.

8.3.2 TRAINING

In a continuous improvement process, organizations should include in their training strategy a plan to focus on GSCM. From an executive perspective, it is important for the people with a leadership role to master GSCM concepts in order to usher in a cultural change. When top management is aware of environmental issues, GSCM will be easier to integrate into the global enterprise strategy.

By promoting GSCM practices and providing GSCM training to suppliers, organizations will be able to manage supply chain risks and ensure a better environmental performance of their supply chain. Transferring strategic knowledge and information to suppliers, and vice-versa, builds a strong collaboration relationship and can create a competitive advantage for both parties.

Training key employees in the operations, design or procurement departments is crucial to ensuring the success of the GSCM strategy. Training sessions should be tailored to their specific roles and responsibilities.

~ GSCM course by MIT

~ GSCM glossary of the IAEG

8.3.3 DATA MANAGEMENT

GSCM requires that data to be exchanged with peer networks of practitioners within the organization and with suppliers, which involves several constraints, including data format and confidentiality. For example, to facilitate data exchange for hazardous substances, a data format called the Materials and Substances Declaration for the Aerospace and Defence, and Other Industries standard (IPC-1754) was created in partnership with the IAEG. It describes how to request data from another supplier tier using the bill of material (BOM) and supplier-to-customer part number association.

Many web platforms are available for data collection among suppliers and can simplify the data collection process with useful tools.

- Introduction to the IPC-1754 Materials Declaration Standard
- Supply Chain Stewardship with Verisk 3E: streamlined exchange of material, product and supplier information throughout the supply chain
- Ecovadis: a business sustainability rating provider
- Enablon: supplier evaluation tool

8.4 GSCM OPERATIONAL GUIDES

This section provides high-level operational guides for the three main pillars of GSCM: green sourcing for purchasers, green design for engineers and green manufacturing for plant managers. Each guide describes the main steps of an implemented green sourcing, design or manufacturing process and provides an example of an avionics application for each step. These guides are intended mainly for OEMs. However, they can also be used by suppliers. The guides are summarized in the form of "to-do" checklists in Appendix C.

TOOL: SUBSTANCE DECLARATION SPREADSHEET AND DATA FORMAT

Aerospace companies are subject to numerous regulations around the world regarding the use of chemical substances, many of which are described in section 4. Therefore, original equipment manufacturers (OEMs) need to be aware of the regulated substances in the products they buy. To standardize the way suppliers respond to customer requests, the IAEG has developed tools for chemical substance declaration:

- The Aerospace and Defence Declarable Substances List (AD-DSL)
- The IPC-1754 XML template standard for substance declaration to request, receive and exchange streamlined data about substances used in products and processes at all levels of their supply chains
- A reporting tool in Excel format
- Supporting material

8.4.1 GREEN SOURCING FOR PURCHASERS

	KEY ACTIVITIES	CASE STUDY GREEN SOURCING FOR AVIONICS
STEP 1 Look for existing commitments	Learn about your organization's **environmentally responsible procurement policy or code for suppliers.** It may already contain established green purchasing specifications (green specifications) or relevant programs for your product categories. If no such document exists, ask your company's **corporate responsibility or sustainability department** to identify the relevant environmental risks in the supply chain. If neither of these options is applicable, you will have to establish your own green specifications, as described in the following steps.	Since the production of electronic components involves hazardous substances, an organization purchasing avionics may already have a policy requiring REACH-compliant purchases.
STEP 2 Discuss procurement needs	When an internal customer (requestor) contacts you to select a supplier for purchasing goods or services, discuss the following items: ~ Is the request in line with the company's environmental commitments? ~ Is the product or service used optimally? Would less quantity be satisfactory? ~ Is the product over packaged?	It may not be possible to reduce the amount of avionics components purchased for an aircraft, but it may be possible to reduce the packaging in which they are shipped.
STEP 3 Identify green specifications	Select green specifications at the product or supplier level relevant to your product category based on: ~ Your company's green sourcing commitment ~ Sustainability team ~ Section 5 and Appendix B (fact sheets on standard parts, avionics and composites) of this document ~ Applicable laws (see Appendix A) ~ Credible and relevant green labels and certifications	The REACH Regulation restricts the use of hazardous substances of products produced or exported to Europe. Even if your company does not export to that part of the world, a relevant green specification for avionics is to require REACH compliance.

STEP 4 Seek supplier feedback	Open a **dialogue** with suppliers about the selected green specifications: ~ Communicate green specifications to suppliers and bidders ~ Specify the importance of the green specification in your supplier selection process ~ Evaluate the current suppliers' green specification compliance (see supply chain survey in section 5.1.1) ~ Publish a request for information to get an overview of suppliers offering products with green specifications Consider other green specifications suggested by suppliers.	Tell your suppliers you intend to require that products with content in substances of very high concern (SVHC) must comply with the REACH Regulation. The specification should also mention that the supplier will be responsible to perform the required due diligence and to provide your company with the necessary information so you can fill out the Material Declaration Form. Some suppliers may export to or have customers in Europe, so their products may already be REACH-compliant.
STEP 5 Select suppliers	Taking into account supplier feedback, integrate green specifications in the **Request for Proposal (RFP)** document and provide scoring methodology. Review candidate suppliers' answers to the RFP along with the other purchasing criteria: ~ Identify whether suppliers are proposing a product that exceeds the set requirements ~ Do not automatically discard non-compliant suppliers. An action plan for compliance can be arranged with the supplier	Favour suppliers that ensure they are REACH-compliant and provide the necessary information to your company. Assign a higher score if a supplier mentions it has integrated green design components (such as easy disassembly) in the product.
STEP 6 Follow-up	Follow **performance metrics** related to the green specifications (e.g. impact reduction and cost savings). Work with suppliers that need to improve their environmental performance. Share **success stories** with other purchasers and suppliers.	Monitor the number of REACH-compliant suppliers. Aim for 100% compliance within two years, for example.

~ Thales' Sustainable Procurement Guide
~ Responsible sourcing guide by the International Council on Mining & Metals (ICMM)
~ Responsible sourcing at ArcelorMittal

8. 4. 2 GREEN DESIGN FOR ENGINEERS

	KEY ACTIVITIES	CASE STUDY GREEN SOURCING FOR AVIONICS
STEP 1 Gather environmental data	Identify the potential environmental impacts of the product throughout its entire **life cycle.** Life cycle assessment (LCA) tools can provide relevant data on the potential impacts of a product over its life cycle.	Environmental hotspots of avionics over the life cycle arise mainly in the following stages (see fact sheet on avionics in appendix B for more details): ~ Raw material acquisition ~ Parts manufacturing ~ Aircraft use stage
STEP 2 Develop and select green designs	Identify relevant green design specifications in the development of possible design solutions, such as (see section 5.2): ~ selecting responsible and non-hazardous materials ~ using LCA and life cycle-based metrics ~ favouring material circularity ~ Promoting additive manufacturing Take into account the gathered environmental data when you choose the most promising design solution	To address the identified hotspots, avionics design could: ~ Include lighter parts ~ Use hazardous substance-free materials
STEP 3 Prototype and test	Develop a product **prototype.** **Test** equipment for functionality. Determine if test results meet success criteria.	Choose avionics components with lighter materials (e.g. replacing copper conductors with fibre optics). Choose electronic components that are manufactured in compliance with international standards on the restriction of hazardous substances (e.g. REACH).
STEP 4 Redesign	Determine if use has proven to be **reliable** and provides anticipated results. Identify other areas where **improvements** could be achieved based on test results.	Tests could reveal that fibre optics greatly increase the device's performance and could be deployed to other devices.

~ Bombardier Transportation's Design for Environment Guidelines

8. 4. 3 GREEN MANUFACTURING FOR PLANT MANAGERS

	KEY ACTIVITIES	CASE STUDY GREEN SOURCING FOR AVIONICS
STEP 1 Identify environmental hotspots	Measure or estimate the environmental metrics of plant operations over a targeted period (e.g. three months) to identify areas of intensive consumption of energy, consumables and water, as well as waste generation.	Identify environmental hotspots at your plant: manufacturing semiconductor components uses fluorine-based substances for chemical etching, depositing thin film or removing residual materials. These substances are associated with very high global warming potentials, which can contribute significantly to increasing the carbon footprint of the product's life cycle.
STEP 2 Develop action plan	Create a **working group** with representatives from various departments who will be responsible for developing and implementing the action plan for your plant. Identify **key performance indicators (KPIs)** for strategic initiatives and set targets, as well as a timeline. Estimate cost savings to provide incentives for deployment of an action plan.	Identify the main sources of GHG emissions (including fluorinated compounds) and evaluate the possibility of using mitigation technologies to reduce/eliminate emissions from these substances.
STEP 3 Implement action plan	**Implement** identified initiatives. Ensure the implementation team reviews the **progress** of the implementation process. Start measuring preliminary results and **communicate KPIs** to the implementation team. **Train** the employees on the new processes, if required.	Implement new manufacturing processes or mitigation technologies at the semiconductor manufacturing plant.
STEP 4 Review results and improve	Review results with the implementation team and assess whether **targets** have been reached. Decide if the initiatives should be kept, modified or **improved.** Identify next steps for **continuous improvement.**	Track GHG emissions at the manufacturing facility and compare with a baseline case. Evaluate further emission reductions as a next step.

~ Guide to Developing an Environmental Management System by the U.S. EPA

Appendix A Summary of environmental regulations affecting the aerospace industry

Image courtesy of Bell Helicopter Textron Canada Ltd.

Below are a few environmental regulations that were identified with industry partners as relevant to the aerospace sector.
Note that this is not a comprehensive list; many other environmental laws apply to this sector. Moreover, this section has absolutely no legal value and serves for information purposes only.

CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA, 1999)

CEPA was adopted in 1999 with the aim of protecting the environment and human health. One of the main components of the legislation is to set out the process of assessing the risks to the environment and human health posed by substances in commerce. It also imposes timeframes for managing toxic substances and ensures the most harmful ones are phased out. Various regulations have been adopted under the umbrella of CEPA to govern the import, manufacture, use and movement of hazardous substances in Canada. Companies operating in Canada therefore have a set of obligations and must ensure they declare any toxic substance that may be imported, produced or released into the environment. Business representatives (executive team and board members) can be held personally accountable if the business fails to comply with the CEPA requirements.

CEPA also includes requirements on renewable fuel content in gasoline and diesel, which can affect some aircraft types.

~ canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/related-documents.html

REGISTRATION, EVALUATION, AUTHORISATION AND RESTRICTION OF CHEMICALS (REACH, EC 1907/2006)

The REACH Regulation was adopted by the European Union (EU) in 2006 and targets chemical substances. Under this legislation, the industry is responsible for managing the risks related to the chemicals it produces and for providing safety information on the substances. Manufacturers and importers are responsible for gathering the relevant information (such as on the substance's composition, manufacture and use), handling the substances safely and registering the information in a centralized database. They must identify the risks associated with the substances and how these risks are managed. Substances had to be registered by May 31, 2018, to be imported into or manufactured in the European Economic Area (EEA, i.e. European Union members, Iceland, Norway and Liechtenstein). REACH targets over 30,000 chemical substances, produced or manufactured, in a volume of more than a tonne per year.

REACH also restricts the use of substances of very high concern (SVHCs). The strictest restrictions apply to SVHCs on the Authorisation List, which have been banned or phased out in the EEA unless granted authorization for a specific use or exempted from authorization. Moreover, unless exempted, SVHCs on the Candidate List contained in items imported in the EEA must be reported to the European Chemicals Agency (ECHA) if the imported amount exceeds one tonne per year and if it is present above a concentration of 0.1% in the imported product's mass. The Candidate List is updated in June and December every year.

This regulation particularly affects the aerospace and defence industries, which use very specialized substances and mixtures, since alternate substances cannot easily be found due to compliance and testing requirements. Discontinuation

of certain substances or supplier reformulation due to REACH creates a business continuity risk for users. Moreover, a finished product manufacturer exporting to the EEA is subject to REACH substance use restrictions. Suppliers who do not export directly to the EEA are not covered by the regulation, but may have to provide information beyond safety data sheets to customers who do export to the EEA.

Many hexavalent chromium compounds are on the SVHC Authorisation List. Therefore, their use in the EEA requires or will require authorization. Such compounds are still used in aerospace, but many have been granted authorization.

~ iaeg.com/elements/pdf/iaeg_reach_chemical_report_06_09_17.pdf

~ echa.europa.eu/regulations/reach/understanding-reach

~ echa.europa.eu/applications-for-authorisation-previous-consultations

TOXIC SUBSTANCES CONTROL ACT (TSCA)

The TSCA was adopted by the United States in 1976 and is administered by the EPA, which regulates the introduction of new or existing chemicals. The Act was amended in 2016, with the adoption of the TSCA Inventory Notification Rule. The new amendment requires all manufacturers or importers of chemicals in the United States to review and designate chemicals that were active during the 10-year period (June 21, 2006 to June 21, 2016). All chemicals active until October 5, 2018, must also be declared. Once this process is finalized, the EPA will release a Final Inventory List (March 4, 2019) and subjected businesses will need to review the list to verify the status of the substances in the U.S. Toxic substances that are declared inactive may no longer be used by businesses. The imported or processed chemical substances contained in an item are not subject to the declaration requirements.

~ iaeg.com/tsca

~ epa.gov/tsca-inventory

RESTRICTION OF HAZARDOUS SUBSTANCES DIRECTIVE (ROHS)

RoHS is a directive from the EU originally published in 2002. The last version, from 2015, restricts the use of the following 10 hazardous substances in electrical and electronic products sold in the EU.

The law was adopted because the targeted hazardous substances present risks during the manufacturing phase of the products, but also because the conditions in which the products are disposed of at their end of life cause a serious risk to human and environmental health.

RoHS impacts the entire consumer electronics industry and many electrical products. Since July 1, 2006, all applicable products present in the EU market have been required to pass RoHS compliance. Other jurisdictions, such as China, Japan, California, Korea, Norway, Turkey and Singapore, have developed their own version of RoHS.

Compared to REACH, the scope of RoHS is narrower. It targets only 10 substances in electrical and electronic products, does not require registration from substance manufacturers and does not restrict the production volume of the restricted substances in the EU.

THE RESTRICTED SUBSTANCES UNDER ROHS[3]

SUBSTANCES		RESTRICTED LIMIT (%)
Lead	Pb	0.1
Mercury	Hg	0.1
Hexavalent chromium	CrVI	0.1
Cadmium	Cd	0.01
Polybrominated biphenyls	PBB	0.1
Polybrominated diphenyl ethers	PBDE	0.1
Bis (2-ethylhexyl) phthalate	DEHP	0.1
Butyl benzyl phthalate	BBP	0.1
Dibutyl phthalate	DBP	0.1
Diisobutyl phthalate	DIBP	0.1

3 Adapted from: DEFRA, RoHS Directive Guidance (assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/679655/rohs-directive-guidance.pdf)

Although means of transport for people and goods and military equipment are excluded from its scope, compliance to the RoHS directive is considered as a GSCM practice. However, RoHS-compliant devices may not be compliant with the stringent technical requirements of the aerospace industry. For example, lead-free electronics are not compatible with "high reliability" application and should not be installed in an aircraft unless they comply with reliability requirements.

The Waste Electric and Electronic Equipment Directive (WEEE 2012/19/EU) is another directive that was adopted to complete RoHS by addressing the end-of-life treatment of electronics. However, it does not apply to equipment intended for use in means of transportation.

rohsguide.com

OTHER

There are various other regulations that apply to the aerospace sector and that may target a specific issue, such as ozone-depleting substances, battery management, etc. Here is a list of relevant laws accompanied by a short description.

NAME (START DATE)	COUNTRY OR REGION	SHORT DESCRIPTION	RELEVANCE FOR AEROSPACE
ECHA Biocidal Products Regulation (2013)	EU	Active substances in biocidal products are limited to a list. Any new active substance must be approved before use. Before entering the market, biocidal products must be authorized.	Biocidal products are present in aircraft interiors. Interior parts suppliers must be aware of this legislation to avoid the use of unapproved active substances.
EU Regulation 2017/821 on conflict minerals (2021)	EU	This regulation forbids importation into the EU of four conflict minerals and metals, i.e. tin, tantalum, tungsten and gold. They are traded from politically unstable areas where environmental laws are likely not enforced. Their use by smelters and refiners is also regulated.	The aerospace industry extensively uses electronics and computer products, which can contain metals from conflict zones.
Japan CSCL (2011, latest version)	Japan	The Chemical Substance Control Law is similar to REACH. It controls the manufacture and import of chemical substances in Japan. It requires use notification and restricts or bans some substances.	It is prohibited to manufacture and import decabromodiphenyl ether except for essential use. For the list of controlled substances, see: www.nite.go.jp/en/chem/kasinn/lists.html
Korea REACH (Jan. 1, 2019, latest version)	South Korea	The Act on the Registration and Evaluation of Chemicals requires to report and register existing chemicals manufactured or imported at a rate of 1 ton/year or higher and new chemicals produced or imported at 100 kg/year. Manufactured and imported products containing more than 0.1% priority control substances and a rate of 1 tonne/year must be reported.	As for other jurisdictions, the Korea REACH is likely to restrict substances used in the aerospace and defence sector.
Montreal Protocol (1989)	197 countries	Protocol for ozone-depleting substances (ODSs) such as chlorofluorocarbons (CFCs) and halons. The treaty was amended in 2016 to include HFCs, which are used as replacements in air conditioners, refrigerators and fire protection, but have high global warming potential.	According to an EU report, the defence sector was historically a significant user of ODSs and it has taken the industry nearly 18 years since the treaty to apply the ban.
Stockholm Convention (2004)	181 countries	Convention aiming to eliminate or restrict persistent organic pollutants (POPs), which bioaccumulate in the food chain.	Decabromodiphenyl ether, used in spare parts, was recommended for inclusion in the convention along with an exemption for the aerospace industry.

Appendix B
Fact sheets

During the GARDN GSCM project, three areas of the aerospace supply chain, or clusters, were analyzed in more detail: **standard parts, avionics and composites.** The analysis used a life cycle based approach (LCA) to identify the clusters' environmental hotspots. The goal was to formulate specific green sourcing and design recommendations for the three clusters identified as important. Three fact sheets present the results and recommendations for each cluster. Each contains the following elements:

- The definition of the cluster.
- The environmental hotspots in the product's life cycle (raw material production, part manufacturing, assembly, use and end of life) based on a literature review. Pinpointing environmental hotspots allows to identify "green opportunities," otherwise known as options or strategies, which can be used to mitigate the impacts of the hotspots.
- A list of green specifications and green designs relevant to each identified green opportunities. Each environmental opportunity is assigned a priority level (low, medium, high) based on the gravity of the environmental issues covered in the 360 reports using a life cycle approach.

Note that applying green sourcing and green design specifications for the three clusters is challenging.

For standard parts and avionics, the information required to apply the proposed green specifications may not always be available. Standard parts and avionics are produced by a large number of manufacturers and sold by several distributors. As a result, the parts that comply with environmental specifications can become indistinguishable from other similar parts. More specifically to standard parts, since the metals to manufacture them are usually commodities traded on the spot and derivative markets, there is little to no traceability to link a standard part to the original producer or site where raw materials were extracted. Nevertheless, the proposed specifications can be useful to initiate a discussion with producers or resellers and to inform the supply chain about the purchasers' concerns and expectations regarding the environmental performance of standard parts and avionics.

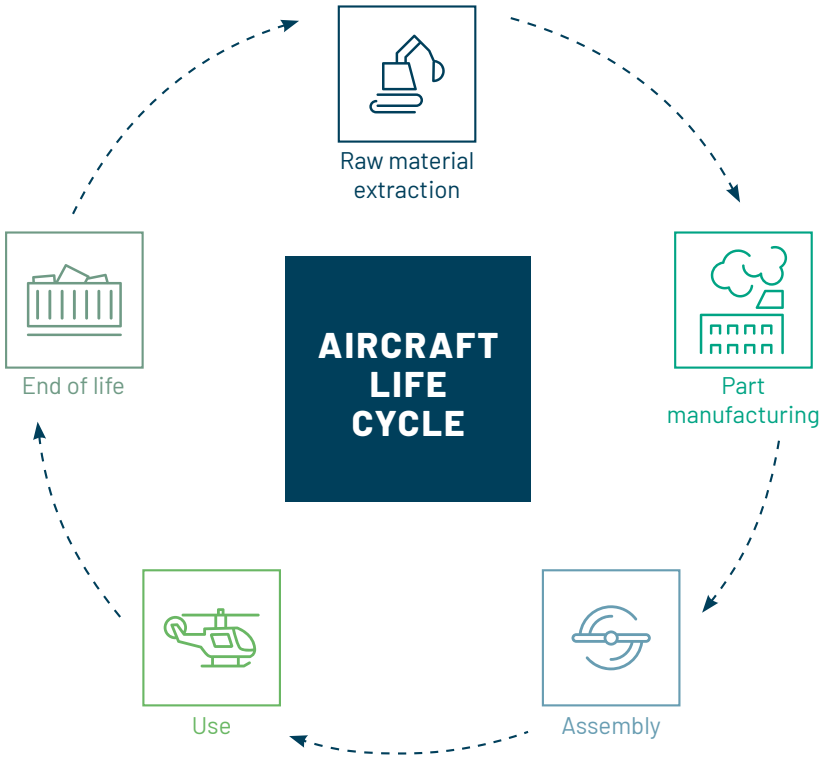
For composites, very few green specifications were found. Therefore, mostly generic recommendations that are not specific to composite materials were provided. However, several recommendations regarding material selection were found for specifications for design for the environment (DfE).

STANDARD PARTS

WHAT ARE STANDARD PARTS?

The standard parts covered in this report include aircraft fasteners such as bolts, screws, studs, structural nuts, skin fasteners, collars, inserts and washers, rivets, pins, blind fasteners, captive screws and panels, and sandwich panel fasteners. Fasteners can be made out of alloyed metals including different types of steel, titanium and aluminum alloys. They undergo different heat and surface treatments to give them specific mechanical and chemical properties.

WHAT ARE THE POTENTIAL ENVIRONMENTAL HOTSPOTS OF STANDARD PARTS OVER THEIR LIFE CYCLE?



RAW MATERIAL PRODUCTION

- **Ore extraction and treatments** are energy intensive and produce greenhouse gas (GHG) emissions. **Mine operations** can disturb ecosystem habitats and release toxic substances into the environment.
- **Metal production** is also an energy and carbon intensive life cycle stage.

PARTS MANUFACTURING

- Processes like **hot forming and heat treatments** increase energy consumption and GHG emissions in the manufacturing stage.
- **Surface finishing** involves the use of toxic substances that have harmful effects on human health and ecosystems.

AIRCRAFT USE STAGE

- The total weight of standard parts contributes to **aircraft fuel consumption,** which leads to significant GHG emissions.

WHAT PRODUCT SPECIFICATIONS BEST ADDRESS THESE HOTSPOTS?

ENVIRONMENTAL HOTSPOT 1 – RAW MATERIAL PRODUCTION

OPPORTUNITIES	GREEN SPECIFICATIONS
Use standard parts made of greener steel/ aluminum/titanium **Priority: High**	Look for company or supplier certification for the adoption of industry best practices (energy efficiency, pollution prevention, waste management, appropriate remediation, etc.).

CERTIFICATIONS	WHY?
Responsible Steel Certification	Steel part suppliers certified in the Responsible Steel standard commit to reduce their GHG emissions, minimize the impacts of mining waste and address mining impacts on water management, ecosystems and biodiversity. ~ see: https://www.responsiblesteel.org/about/
IRMA Standard for Responsible Mining	Under IRMA (Initiative for Responsible Mining Assurance), mining companies will be required to have measures addressing waste, water and pollutant management, GHG emissions, biodiversity and ecosystem services at one or many of their mining sites. ~ see: http://www.responsiblemining.net/certification/
Aluminum Stewardship Initiative (ASI)	Entities and facilities engaged in the aluminum value chain certified in the ASI Performance Standard address environmental sustainability (GHG emissions, emissions/effluents/waste, water and biodiversity). ~ see: https://aluminium-stewardship.org/asi-standards/asi-performance-standard/

Other useful resources/tools:

Towards Sustainable Mining (TSM) initiative: The TSM program is mandatory for all members of the Mining Association of Canada for their operations in Canada and offers best practices guidance and useful tools to improve their environmental performance.

~ see: http://mining.ca/fr/vers-le-d%C3%A9veloppement-minier-durable

GRANTA Material intelligence: A material database that provides environmental data on different materials.

~ see: https://www.grantadesign.com/products/mi/index.htm

ENVIRONMENTAL HOTSPOT 2 – PART MANUFACTURING (ENERGY CONSUMPTION)

OPPORTUNITIES	GREEN SPECIFICATIONS
Choose suppliers whose practices are energy efficient and promote low GHG energy sources **Priority: Medium**	Look for company or supplier certification for the adoption of industry best practices in terms of energy efficiency and GHG emissions.

CERTIFICATIONS	WHY?
Responsible Steel Certification	Steel part suppliers certified in the Responsible Steel standard are required to have a GHG emission reduction program in place to meet specific targets and to keep their company's site emissions below global threshold levels. ~ see: https://www.responsiblesteel.org/about/
Aluminum Stewardship Initiative (ASI)	Entities and facilities engaged in the aluminum value chain certified in the ASI Performance Standard are required to disclose their GHG emissions and energy use, set emission reduction targets and meet GHG emission threshold levels for aluminum smelting operations. ~ see: https://aluminium-stewardship.org/asi-standards/asi-performance-standard/

Other useful resources/tools:

ISO 50001 (Energy management): ISO 50001 requires organizations to implement strategies, management systems, policies and targets to improve energy performance, including energy efficiency, energy use and energy consumption.

~ see: https://www.iso.org/iso-50001-energy-management.html

CDP: Under CDP, companies and organizations disclose their GHG management practices and GHG emissions. For standard parts, this type of assessment is especially relevant for the raw material production and manufacturing stages by providing GHG emissions data to compare companies.

~ see: https://www.cdp.net/en

Canadian Industry Partnership for Energy Conservation (CIPEC): CIPEC is a voluntary industry-government initiative to help companies improve energy efficiency and reduce their GHG emissions. Participation in this initiative gives companies access to useful resources and tools that promote energy efficiency, including technical guidebooks, the ISO 50001 standard, studies on process integration and computational fluid dynamics, and online presentations on energy practices.

~ see: https://www.nrcan.gc.ca/energy/efficiency/industry/cipec/20341

Environmental product declaration (EPD): Although few EPDs have focused on aerospace products or components, EPDs are useful tools to collect transparent and high-quality information about the life cycle environmental impact of products and materials.

~ see: https://www.environdec.com/What-is-an-EPD/

ENVIRONMENTAL HOTSPOT 2 – PARTS MANUFACTURING (HAZARDOUS SUBSTANCES IN SURFACE FINISHING)

OPPORTUNITIES	GREEN SPECIFICATIONS
Phase out standard parts treated with toxic substances **Priority: High**	Look for standard parts that were manufactured with surface treatments that do not contain hazardous substances (e.g. use of non-cyanide-based plating process).

CERTIFICATIONS	WHY?
REACH compliance	REACH-compliant companies are required to identify and manage risks linked to the substances they manufacture in or import into Europe and to communicate risk management measures to users. ~ see: https://echa.europa.eu/regulations/reach/understanding-reach

Other useful resources/tools:

Use the Surface Engineering Database to avoid chromium hexavalent coatings and identify alternative coating solutions.

~ see: https://www.serdp-estcp.org/asetsdefense/Surface-Engineering-Database

RoHS compliance: RoHS restricts the use of hazardous substances (including lead, cadmium, hexavalent chromium) in electrical and electronic equipment.

~ see: http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm

WHAT PRODUCT DESIGNS ADDRESS THESE HOTSPOTS?

ENVIRONMENTAL HOTSPOT 1 – RAW MATERIAL PRODUCTION
ENVIRONMENTAL HOTSPOT 3 – FUEL CONSUMPTION DURING USE STAGE

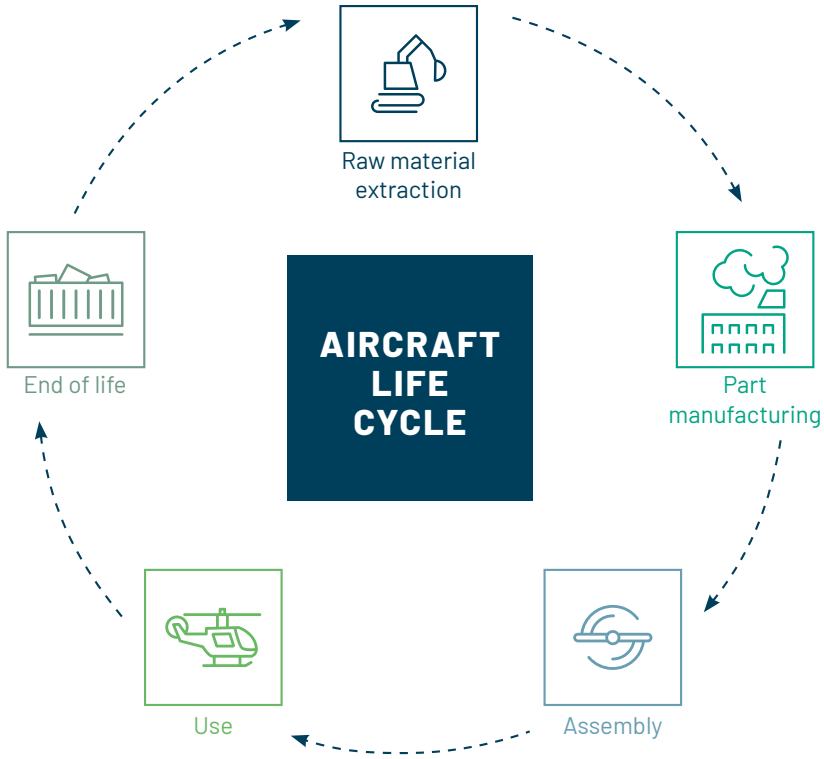
OPPORTUNITIES	DESIGN SPECIFICATIONS
Reduce the number/ weight of standard parts **Priority: High**	~ Use lighter materials such as composites, plastics and titanium ~ Replace fasteners with adhesives ~ Strategically design aircraft components to minimize the number of fasteners needed for the same performance ~ Choose standard part designs that minimize metal use

AVIONICS

WHAT ARE AVIONICS?

Avionics include all electric and electronic systems on an aircraft, including air data and flight instrumentation, navigation and guidance systems, flight control and communication systems and electrical power systems. These systems include a large range of equipment including computers, wires and electronic parts, all of which are made of several metals (i.e. copper, steel, aluminum) and plastics.

WHAT ARE THE POTENTIAL ENVIRONMENTAL HOTSPOTS OF AVIONICS OVER THEIR LIFE CYCLE?



RAW MATERIAL ACQUISITION

~ **Ore extraction and treatments** are energy intensive and produce GHG emissions. **Mine operations** can disturb ecosystem habitats and release toxic substances into the environment.

~ **Plastic production** is also an energy- and carbon-intensive life cycle stage.

PARTS MANUFACTURING

~ The shape forming and heat treatment processes of metal parts and the use of fluorinated compounds with high global warming potential in the subtractive manufacturing processes for components like semiconductors increase the GHG emissions in the manufacturing stage.

~ The production of electronic components involves hazardous substances that are potentially harmful for human health and ecosystems. Risks of exposure are especially high during the production phase and the final treatment of electronic waste.

AIRCRAFT USE STAGE

~ The total weight of avionics contributes to **aircraft fuel consumption,** which leads to significant GHG emissions over their life cycle.

LOW RECYCLING RATE OF USED AVIONICS

~ A low recycling rate of electronic components that have reached their end of life generates metal and plastic waste, which could otherwise be used to produce new components. This would reduce the environmental impacts in the raw material acquisition stage.

WHAT PRODUCT SPECIFICATIONS BEST ADDRESS THESE HOTSPOTS?

ENVIRONMENTAL HOTSPOT 1 - RAW MATERIAL ACQUISITION

OPPORTUNITIES	GREEN SPECIFICATIONS
Use electronic components containing recycled plastics **Priority: Medium**	Look for company or supplier certifications for the adoption of industry best practices in terms of recycled material use. **Useful resources/tools:** EPEAT (Electronic Product Environmental Assessment Tool) requires that the plastic materials used in specific electronic products contain a minimum amount of post-consumer recycled content. EPEAT covers mainly PCs, imaging equipment and televisions and is therefore not directly applicable to aerospace avionics. Nevertheless, EPEAT's guidelines can provide a framework as well as useful criteria to develop green supply programs or initiatives. ~ see: https://greenelectronicscouncil.org/epeat/epeat-overview/

ENVIRONMENTAL HOTSPOT 2 - HAZARDOUS SUBSTANCES IN PARTS MANUFACTURING

Phase out electronic components that contain hazardous substances

Priority: Medium

Look for avionics whose electronic components are manufactured in compliance with international standards on the restriction of hazardous substances.

CERTIFICATIONS	WHY?
Hazardous Substances Process Management (HSPM) certification from the IECQ	The HSPM requires electronic component manufacturers and suppliers to demonstrate compliance with national and international hazardous substance-free requirements such as REACH and RoHS. ~ see: http://www.iecq.org/about/hspm-scheme/ *IECQ: International Electrotechnical Commission Quality Assessment System for Electronic Components*
REACH compliance	REACH-compliant companies are required to identify and manage risks linked to the substances they manufacture in Europe and to communicate risk management measures to users. Furthermore, compliance with REACH implies that the electronic component does not contain substances of very high concern (SVHC). ~ see: https://echa.europa.eu/regulations/reach/understanding-reach
RoHS compliance	RoHS restricts the use of hazardous substances (including lead, cadmium and hexavalent chromium) in electrical and electronic equipment. Although avionics have not been mentioned specifically in the categories of electronic products covered by the RoHS legislation, component suppliers are likely to shift towards hazardous substance free components as a result of pressure from other industries that are regulated by the RoHS legislation. **NOTE: RoHS-compliant devices may not be compliant with the stringent technical requirements of the aerospace industry. For example, lead-free electronics are not compatible with "high reliability" application and should not be installed in an aircraft unless they comply with reliability requirements.** ~ see: http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm

Other useful resources/tools:

The declaration tools for chemical substances developed by the International Aerospace Environmental Group (IAEG), in particular the list of substances subject to international regulations, include useful information on the substance content of several aerospace products.

~ see: www.iaeg.com/chemicalrpt/

Developed by the Health Product Declaration Collaborative (HPDC), health product declarations (HPDs) report a product's content and assess the health risks associated with the individual ingredients contained in the product. Existing HPDs for electrical products can be viewed on the Health Product Declaration Collaborative (HPDC) website.

~ see: https://www.hpd-collaborative.org/hpd-public-repository/

Use the Surface Engineering Database to avoid chromium hexavalent coatings and identify alternative coating solutions.

~ see: https://www.serdp-estcp.org/asetsdefense/Surface-Engineering-Database

Choose suppliers whose practices are energy efficient and promote low GHG energy sources

Priority: High

Look for company or supplier certification for the adoption of industry best practices in terms of energy efficiency and GHG emissions such as:

CERTIFICATIONS	WHY?
EPEAT	Under EPEAT, manufacturers must demonstrate that fluorinated GHG emissions have been reduced by 90% at the manufacturing plants. ~ see: http://greenelectronicscouncil.org/epeat/epeat-overview/

Other useful resources/tools:

ISO 50001 (Energy management): ISO 50001 requires organizations to implement strategies, management systems, policies and targets to improve energy performance, including energy efficiency, energy use and energy consumption.

~ see: https://www.iso.org/iso-50001-energy-management.html

CDP: Under CDP, companies and organizations disclose their GHG management practices and GHG emissions. For avionics, this type of assessment is especially relevant for the raw material production and manufacturing stages by providing GHG emissions data to compare companies.

~ see: https://www.cdp.net/en

Canadian Industry Partnership for Energy Conservation (CIPEC): CIPEC is a voluntary industry-government initiative to help companies improve energy efficiency and reduce their GHG emissions. Participation in this initiative gives companies access to useful resources and tools that promote energy efficiency, including technical guidebooks, the ISO 50001 standard, studies on process integration and computational fluid dynamics, and online presentations on energy practices.

~ see: https://www.nrcan.gc.ca/energy/efficiency/industry/cipec/20341

Environmental product declaration (EPD): Although few EPDs have focused on aerospace products or components, EPDs are useful tools to collect transparent and high-quality information about the life cycle environmental impact of products and materials.

~ see: https://www.environdec.com/What-is-an-EPD/

ENVIRONMENTAL HOTSPOT 2 - HAZARDOUS SUBSTANCES IN PARTS MANUFACTURING
ENVIRONMENTAL HOTSPOT 4 - LOW RECYCLING RATE OF USED AVIONICS

OPPORTUNITIES	GREEN SPECIFICATIONS	
Improve the recovery of electronic components **Priority: Medium**	Look for company or supplier certifications for the adoption of industry best practices in terms of electronic recycling and recovery at the end-of-life stage of an aircraft.	
	WEEE compliancy	The WEEE (Waste Electrical and Electronic Equipment) regulations force producers to be responsible for the end-of-life treatment of their products, including the identification of hazardous substances. ~ see: http://ec.europa.eu/environment/waste/weee/index_en.htm
	ISO 11469:2016	Generic identification and marking of plastics products.

WHAT PRODUCT DESIGNS ADDRESS THESE HOTSPOTS?

ENVIRONMENTAL HOTSPOT 1 - RAW MATERIAL ACQUISITION
ENVIRONMENTAL HOTSPOT 3 - FUEL CONSUMPTION DURING USE STAGE

OPPORTUNITIES	DESIGN SPECIFICATIONS
Reduce the number/ weight of avionics **Priority: High**	Replace numerous line replaceable units (LRU) with fewer integrated modular avionics (IMA) centralized units in order to reduce the number of electronic units. By reducing the hardware in avionics computers, the IMA approach can significantly reduce avionics weight. Choose avionics components with lighter materials (e.g. replacing copper conductors with fibre optics, choosing thinner wire insulation materials capable of resisting higher temperatures).

ENVIRONMENTAL HOTSPOT 3 - FUEL CONSUMPTION DURING USE STAGE

OPPORTUNITIES	DESIGN SPECIFICATIONS
Improve component performance **Priority: High**	Improve aircraft navigation with more efficient avionics to potentially reduce the flight's travelled distance, especially in inclement weather, leading to a reduction in the amount of fuel consumed. Indeed, a navigation system which provides real-time updates on adverse weather and wind conditions can help the aircraft take faster routes in more favourable weather conditions. Optimized profile descents, tailored arrivals and optimized en route flights are a few examples of procedures supported by avionics that lead to aviation fuel savings. Use real-time data on air traffic conditions to more accurately predict the aircraft's position, allowing for the optimization of arrival and departure paths. Design avionics to better handle continuous climb, cruise and descent operations, which can also reduce aircraft fuel consumption since these operations conserve fuel and reduce the use of power settings compared to the standard step-down approach.

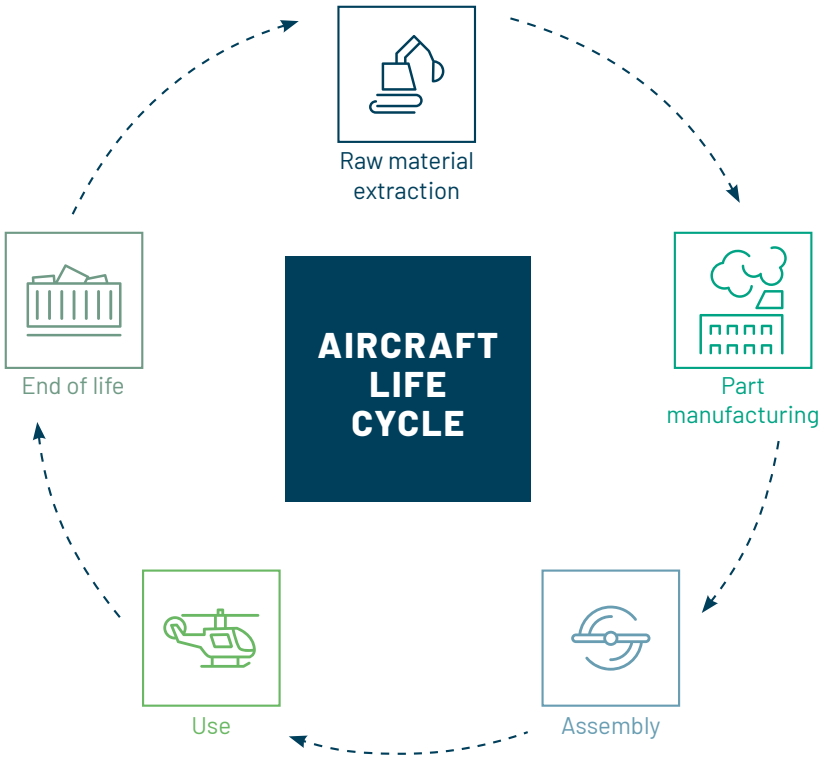
COMPOSITES

WHAT ARE COMPOSITE MATERIALS?

Composite materials are a combination of two or more dissimilar materials that combine their best properties or create a new set of characteristics that neither of the constituent materials could achieve on their own. Composite materials are typically created from individual continuous, straight fibres (e.g. carbon, glass, aramid, etc.) embedded in a host polymer matrix (e.g. phenolic, polyester, epoxy, etc.), which are laminated layer by layer to build up the final material/structure. The opposite figure shows an example of what a composite is.

Applications of composite materials on aircraft include: fairings, flight control surfaces, landing gear doors, leading and trailing edge panels on the wing and stabilizer, interior components, floor beams and floorboards, vertical and horizontal stabilizer primary structure on large aircraft, primary wing and fuselage structure on new generation large aircraft, turbine engine fan blades, and propellers.

WHAT ARE THE POTENTIAL ENVIRONMENTAL HOTSPOTS OF COMPOSITE MATERIAL PARTS OVER THEIR LIFE CYCLE?



PARTS MANUFACTURING

- **Matrix production** involves corrosive chemicals (aromatic, aliphatic amines) that may impact human health (skin and lung irritation, allergic and asthmatic reactions).
- **Composite material production** is energy intensive and may result in significant emissions to the atmosphere, including GHGs and particulate matter. Moreover, used materials may emit other substances that may cause environmental impacts or have harmful effects on human health.
- **Surface finishing** may require toxic substances causing health issues and environmental impacts. Moreover, surface finishing may liberate short fibres, allowing them to become airborne. Such fibres may damage lung tissue.

AIRCRAFT USE STAGE

- **Maintenance:** The resins in composite materials contain chemicals or nanofibres that may cause human health issues during maintenance activities.
- **Weight reduction:** Using composite material parts enables aircraft weight reductions of 10–40% compared to conventional material parts. This weight reduction can result in significantly lower aircraft fuel consumption and emissions, and other life cycle impacts.

END OF LIFE

- **The recycling of composite material is currently limited** due to their complex heterogeneous structure. **Research is needed** to improve composite material recycling through separation of resin and fibre components (mechanical, thermal or chemical treatment).

WHAT GREEN SPECIFICATIONS BEST ADDRESS THESE HOTSPOTS?

ENVIRONMENTAL HOTSPOT 1 - PART MANUFACTURING – GENERIC SPECIFICATIONS

OPPORTUNITIES	GREEN SPECIFICATIONS
Adopt the best production practices **Priority: High**	Implement the best certifications, recommendations and practices to improve energy efficiency and health safety in the production of composite materials.

CERTIFICATIONS	WHY?
Certified Composites Technician Program	This certification provides the best techniques and practices for the production of composite materials, including safe practices for employees. ~ see: https://acmanet.org/
ISO 9001:2015	ISO 9001:2015 sets out the criteria for a quality management system. ~ see: https://www.iso.org/iso-9001-quality-management.html
SAE AS9100D	This standard includes ISO 9001:2015 quality management system requirements and specifies additional aviation, space and defence industry requirements, definitions and notes. ~ see: https://www.sae.org/standards/content/as9100d/
ISO 14001:2015	ISO 14001:2015 sets out the criteria for an environmental management system; it maps out a framework to set up an effective environmental management system. ~ see: https://www.iso.org/iso-14001-environmental-management.html

Improve occupational health and safety **Priority: High**	Handle harmful substances released during the processing and machining of composite material parts	Matrix materials and fibres may be emitted during manufacturing and surface finishing processes. Some of these materials may have human health-related impacts. Reducing manufacturing employees' potential exposure to these harmful substances is paramount.
	Adopt safety-related requirements, such as those of the Federal Aviation Administration and the European Aviation Safety Agency	These requirements improve the safety of production operations, lowering the exposure of employees to harmful substances and situations.
Check the quality of the composite material parts **Priority: Medium**	Follow standardized procedures to check the quality of the composite material parts to ensure their safety and durability during aircraft operation.	

CERTIFICATIONS	WHY?
ASTM E2662 ASTM E 2580 ASTM E 2581 ASTM E 2582	These standards provide methods to check the quality of the composite material parts. ~ see: https://compass.astm.org/EDIT/html_annot.cgi?E2662 ~ see: https://compass.astm.org/EDIT/html_annot.cgi?E2580 ~ see: https://compass.astm.org/EDIT/html_annot.cgi?E2581 ~ see: https://compass.astm.org/EDIT/html_annot.cgi?E2582

WHAT PRODUCT DESIGNS ADDRESS THESE HOTSPOTS?

ENVIRONMENTAL HOTSPOT 1 - PART MANUFACTURING – ENERGY AND HAZARDOUS SUBSTANCES

OPPORTUNITIES	DESIGN SPECIFICATIONS
Minimize energy consumption and toxic emissions during part production **Priority: High**	The production of composite material parts is associated with high energy consumption and toxic substance usage. It is therefore recommended to improve part design to mitigate both of these issues: reducing energy consumption and limiting harmful emissions.

SPECIFICATIONS	WHY?
Avoid matrices made of toxic materials	Avoiding toxic materials, such as aromatic and aliphatic amines, reduces the potential exposure of the employees manufacturing and maintaining the composite material parts.
Use efficient processes	Efficient processes can save both raw materials and energy while reducing polluting emissions and waste generation. Such processes should be identified during the design stage.

ENVIRONMENTAL HOTSPOT 3 - USE STAGE – MAINTENANCE AND FUEL CONSUMPTION

OPPORTUNITIES	DESIGN SPECIFICATIONS
Minimize maintenance activities **Priority: High**	

SPECIFICATIONS	WHY?
Increase use of composite materials in aircraft	Composite material parts are expected to require less maintenance than conventional parts. By reducing maintenance activities, life cycle impacts should be slightly lower due to energy and resources saved from not having to repair and replace defective parts.

Reduce aircraft fuel consumption **Priority: High**	Optimize part design	Reducing parts' weight decreases fuel consumption during the aircraft use stage. Considering the long lifetime of aircraft, even a small drop in weight can greatly cut aircraft life cycle emissions. **Additive manufacturing** is a promising technology to improve part design and reduce part weight.

ENVIRONMENTAL HOTSPOT 4 – END-OF-LIFE MANAGEMENT

OPPORTUNITIES	DESIGN SPECIFICATIONS
Improve end-of-life management **Priority: High**	Composite materials are currently mostly not recycled due to lack of techniques. ~ Develop recycling techniques for composite material parts that are both safe for employees and efficient to recover materials. ~ Use materials in part production that have a high end-of-life value or pathway.

Appendix C Checklist

Image courtesy of Bell Helicopter Textron Canada Ltd.

The following checklist is a summary of the operational guides presented in section 8.4 of the Best Practices Guide for a Greener Aerospace Supply Chain. Each list item corresponds to a step of the corresponding operational guide summarized in a way to keep only the essential information. This checklist is intended mainly for OEMs. However, it can also be used by suppliers.

GREEN SOURCING FOR PURCHASERS

- ☐ Look for existing GSCM commitments in your organization
- ☐ If they exist, check that your purchases are in line with them. If they don't, identify green specifications relevant to your product category by referring to sections 4 and 5.1 of the Best Practices Guide for a Greener Aerospace Supply Chain.
- ☐ Communicate the selected green specifications to your current and potential suppliers and seek their feedback (e.g. publish a request for information containing the green specification[s]).
- ☐ Integrate green specifications in Requests for Proposals (RFPs) and select suppliers.
- ☐ Monitor the product's performance in terms of environmental impacts and cost reductions.

GREEN DESIGN FOR ENGINEERS

- ☐ Identify potential environmental hotspots of your product over its life cycle. For standard parts, avionics and composites, refer to Appendix B of the Best Practices Guide for a Greener Aerospace Supply Chain.
- ☐ Based on that, elaborate green design specifications to take into account when developing and selecting design solutions. For examples, refer to section 5.2 of the Best Practices Guide for a Greener Aerospace Supply Chain.
- ☐ Develop a prototype with the selected design solution that integrates green design specifications, and test it.
- ☐ Based on the test results, improve the green design to meet expectations in terms of technical performance and reliability, if required.

GREEN MANUFACTURING FOR PLANT MANAGERS

- ☐ Measure or estimate environmental metrics of your plant's operations over a targeted period (e.g. consumption of energy, consumables and water, as well as waste generation) to define a baseline performance.
- ☐ Develop an action plan to increase your plant's environmental performance by creating a working group, selecting key performance indicators (KPI), setting targets and a timeline and estimating costs (incl. potential cost savings).
- ☐ Implement the action plan and monitor progress.
- ☐ After implementation, evaluate the action plan's success in terms of targets and identify the next steps.