

DEVELOPMENT OF THE AEROLOGLABTOOL®**Fernando Teixeira Mendes Abrahão**

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ABSTRACT

This work reviews engineering and management aspects that involve and results in support for Complex Systems. The study describes typical aircraft fleet support issues, whether commercial, executive or from the defense sector, but with natural possibilities for similar applications on other fleets of vehicles, rocket launchers, and other Complex Systems. Problems are identified to link their main causes and when it would be appropriate to deal with them so that they could be eliminated or, at least, minimized throughout the system's Life Cycle. It is also discussed reasons why support design gaps occur, their temporality and their causes through content analysis involving Systems Engineering, Integrated Logistic Support approach, the CDIO initiative (Conceive, Design, Implement Operate, cdio.org), design for RAMS, e-Maintenance and other related support approaches and methodologies. The results provide a map of actions, both to guide education and to obtain skills in key areas for solving problems, as well as to drive research projects related to both the treatment of problems and innovation in terms of Complex Systems' support. A collaborative framework (AeroLogLabTOOL®) for research and development is proposed and discussed.

Keywords: Complex Systems; Integrated Logistic Support; Systems Engineering; e-Maintenance.

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1. INTRODUCTION

The AeroLogLabTOOL[®] is a collaborative tool designed to develop the entire set of activities, tools, analyses, and developments involved in the supportability of Complex Systems. AeroLogLabTOOL[®] exists due to the lack of a collaborative and open platform that deals with logistics in the design, development, manufacture, deployment, operation and support, modernization and disposal of Complex Systems, in a shared, integrated, comprehensive, transparent and total way [1].

The items below describe some arguments where the development of such a framework is opportune:

- Lack of a collaborative and open platform for all Life Cycle phases;
- absence of a dedicated, shared, integrated, interactive, comprehensive, transparent and complete framework;
- supportability for Complex Systems is still confusing, delayed, and non-coherent in great part of the industry, operators, agencies, airlines, Maintenance Repair and Overhaul (MRO) in charge of some transportation fleets and academia;
- knowledge in the area is particularly low, little shared and spread, not compliant and almost ignored by academia (compared with aeronautical engineering);
- aeronautical engineering courses ignore the design and development of the supportability of Complex Systems.
- some companies seem to be alright with that;
- the problem lacks a knowledge management approach to be developed and to become common organizational and academic culture, not just for developers but also for fleet operators and maintainers.

Industry, with rare exceptions, prefers to misrepresent the issue and not brag about the grave consequences unless it is too late. The problem lacks a shared knowledge management framework so that it can evolve and become an organizational and academic culture for developers, operators, researchers and fleet maintainers of Complex Systems.

The objective of the AeroLogLabTOOL[®] is, within the Triple-Helix (Govern, Industry and Academia) concept, to develop a collaborative, shared, transparent and open framework of tools for the development and management of all factors affecting the support of Complex Systems for all phases of their respective life cycles.

The objective of this paper is to describe the development of the AeroLogLabTOOL[®].

The text is organized, first, with the introduction of the framework and its purpose. Next, it reviews related topics from industry and academia. Third, it discusses the application of the main modules of the framework. Next, it presents a study case with examples of the

AeroLogLabTOOL[®] utilization. Last, the conclusion and envisaged future developments[1], [2].

2. BACKGROUND

The definition of Complex Systems Logistics Support generally considers three main perspectives and some metrics. The combination and integration of these three perspectives encompass the entire scope of Complex Systems support.

2.1. SUPPORTABILITY SCOPE OF COMPLEX SYSTEMS: MEASURES OF PERFORMANCE

Reliability, Maintainability, Availability and Safety (RAMS) are the measures of performance of great impact on the supportability of Complex Systems. Together they actually describe or are the biggest influencer on operational, logistical and cost behaviors.

Availability permits system's assignment and the mission deploy, Reliability allows the system to complete the mission and Maintainability provides the restoration of the Availability. Therefore, a Complex Systems, to be properly operated, needs the best possible information about RAMS, to provide the expected support performance. If RAMS thresholds are not mature, a huge amount of variability takes place and management becomes a nightmare [3].

2.2. SUPPORTABILITY SCOPE OF COMPLEX SYSTEMS: LIFE CYCLE PERSPECTIVE

One of the components of the supportability scope is the Life Cycle perspective where some logistics considerations are specific, better suited, or convenient for each phase of the development and support of a system's Life Cycle, even though other factors are sound for the development of the entire system Life Cycle span.

Table 1 is inspired by the ASD/AIA SX000i *International guide for the use of the S-Series Integrated Logistics Support (ILS) specifications* and presents a definition of Life Cycle major phases and points to what is supposed to happen on each one.

Table 1 - Life Cycle phases [1]

Phases	Documents		
	SX000i	NATO AAP-20	US DoD 5000.02
Preparation	<ul style="list-style-type: none"> Identify user needs Develop Product Requirements Asses potential material solution Identify and reduce Tech risks Establish a business case including Life Cycle costs estimates 	Pre concept	Material solution
		Concept	Technological development
Development	<ul style="list-style-type: none"> Develop according to user requirements a system that can be produced, tested, evaluated, operated, supported and retired Develop an affordable manufacturing process Ensure operational supportability while minimizing logistics footprint 	Development	Engineering and manufacturing development
Production	<ul style="list-style-type: none"> Produce the product Test the product Conduct product acceptance to confirm that the product satisfies the requirements 	Production	Production and deployment
In service	<ul style="list-style-type: none"> Operate the product Deliver required services with continued operational and cost effectiveness Access, decide on modifications and upgrades Evaluate continuously effectiveness and efficiency Provide support enabling continued Product operation and sustainable service 	Utilization	Operations and support
		Support	
Disposal	<ul style="list-style-type: none"> Demilitarize and dispose of according to legal and regulatory requirements 	Retirement	

2.3. SUPPORTABILITY SCOPE OF COMPLEX SYSTEMS: INTEGRATED LOGISTICS SUPPORT

A second support dimension relates to the Integrated Logistics Support approach, where a comprehensive list of concepts, methodologies, tools, tasks, requirements and issues (also referred as ILS Elements) are timely and integratedly considered to cover every possible constraint affecting the Complex Systems logistics support [3].

The next topics present the ILS elements definition/objective according to two main references: *The Integrated Product Support Element Guidebook*, from the Defense Acquisition University (DAU); and the *ASD/AIA SX000i International guide for the use of the S-Series Integrated Logistics Support (ILS) specifications*, from Defense Industries Association of Europe / ASD-STAN and Aerospace Industries Association. These references are up to date and suit both commercial and defense ILS applications.

In the sequel, follows a simplistic description of the twelve ILS/IPS Elements. For complete definitions see [4][9][10][11]:

1. Maintenance: Involves the maintenance concepts and requirements to ensure the best possible equipment/capability is available when the user needs it at the lowest possible cost.
2. Supply Support: Involves the management actions to acquire and catalog repair parts, spares, and all classes of supply to ensure the best equipment capability is available to support the complex system or maintainer when it is needed at the lowest possible cost.
3. Workforce and Personnel: Involves the personnel with the grades and skills required to: operate equipment, complete tasks, support the complex system operations and activity, and ensure the best capability is available for the operations.
4. Training: Involves the training of personnel to: maximize the effectiveness of the complex system fleet strategy; and to operate/maintain the equipment throughout the systems' Life Cycle.
5. Computer Resources: Involves hardware, software, documentation, work force and personnel necessary for planning and management of Complex system critical computer hardware and software systems.
6. Technical Data: Involves management actions to acquire, develop and produce information and publications to: operate, maintain, and train on the equipment to maximize its effectiveness, safety and availability.
7. Support Equipment: Involves management actions to acquire and support the equipment required to operate and maintain the complex system activities at the lowest Total Ownership Cost.
8. Facilities & Infrastructure: Involves facilities to enable training, maintenance and storage, to maximize the effectiveness of the complex system and the logistic support system at the lowest TOC.
9. Packaging, Handling, Storage & Transportation PHS&T: Involves actions related to packaging and preservation, handling, storage and transportation requirements to maximize availability and usability of the materiel to include support items whenever they are needed for training or mission.
10. Design Interface: Participate in the systems engineering process to impact the design from its inception throughout the Life Cycle, facilitating supportability to maximize the availability, effectiveness and capability of the system at the lowest cost possible.
11. Sustaining Engineering: Support in-service systems in their operational environments and spans those technical tasks to ensure continued operation and maintenance of a system with managed risk.
12. Product Support Management: Plan and manage cost and performance across the product support value chain, from design through disposal and also plan, manage, and fund the complex system product support across all Integrated Product Support (IPS) Elements.

2.4. SUPPORTABILITY SCOPE OF COMPLEX SYSTEMS: SYSTEMS ENGINEERING

The third perspective is the Systems Engineering approach, which is the primary tool to transform requirements into products and services, where support requirements are defined, analysed and solutions designed, implemented, integrated, tested and validated.

Table 2 puts these three dimensions together to map the entire set of activities, iterations and interactions to be developed and considered to support complex systems. The

map presents on the first line, the description of Complex Systems Life Cycle phases while the first column describes the ILS/IPS elements [5].

The Intersection of them would lead to the set of topics required to consider at that specific phase, addressing that specific ILS element, but also giving the visibility to assess what would be the impacts for the following phases, inputs for and consequences of previous developments and integration with other ILS elements.

A Systems Engineering approach is over the entire Map to provide guidance in terms of engineering development efforts devoted to supportability. It is clear that the amount of knowledge involved is tremendous and is case-specific. This Map is a guide for engineering development of the supportability of complex systems.

Table 2 - Life Cycle phases and ILS/IPS Elements [5]

ILS Elements	Life Cycle phases				
	Preparation	Develop.	Production	In Service	Disposal
Maintenance	Concepts, methodologies, tools, tasks, requirements and issues according to the peculiarities of each Life Cycle phase.				
Supply					
Manpower					
Training					
Support Equipment					
Technical Data					
Computer Resources					
Facilities & Infrastructure					
PHS & T					
Sustaining Engineering					
Design Influence					
Product Support Management					

The last topic of this review comes from the experience dealing with weapons systems and some other complex systems throughout their Life Cycles, but especially on the Deployment phase of the first hull numbers delivered. Figure 1 presents what happens when project management does not properly address the supportability requirements. The RAMS threshold maturity is something that needs to be part of the early phases of the development of a complex system. Actually, it should be part of the concept of operations. Even though, some minor gaps may occur for the first deliveries. These potential gaps are a function of the complexity involved and should be part of the maturity growth program with shared risks among users and suppliers during the Deployment phase.

However, a much more complicated scenario may develop. Let us suppose, for any given reason, that almost no support requirements were derived from the concept of operations and only after the development of the first prototypes that some maintenance requirements are really taken into account. In this case, the entire RAMS factors maturity is

way below the expected values. Without knowing the RAMS threshold behaviour, it is almost impossible to manage the readiness of the fleet within cost expectancy.

Figure 1 presents the development of the problems mentioned above. The absence of logistics support engineering at the Concept phase and the lack of understanding by other engineers of logistics requirements may cause the RAMS maturity curve to sleep to the right. The F-4 [6] and B-58 [7] are examples of systems with this behaviour. The first with reliability and maintainability problems resulting in low availability and vast amount of maintenance man-hours per flight hour and, the second, a total disaster in terms of supportability and did not fly mature.

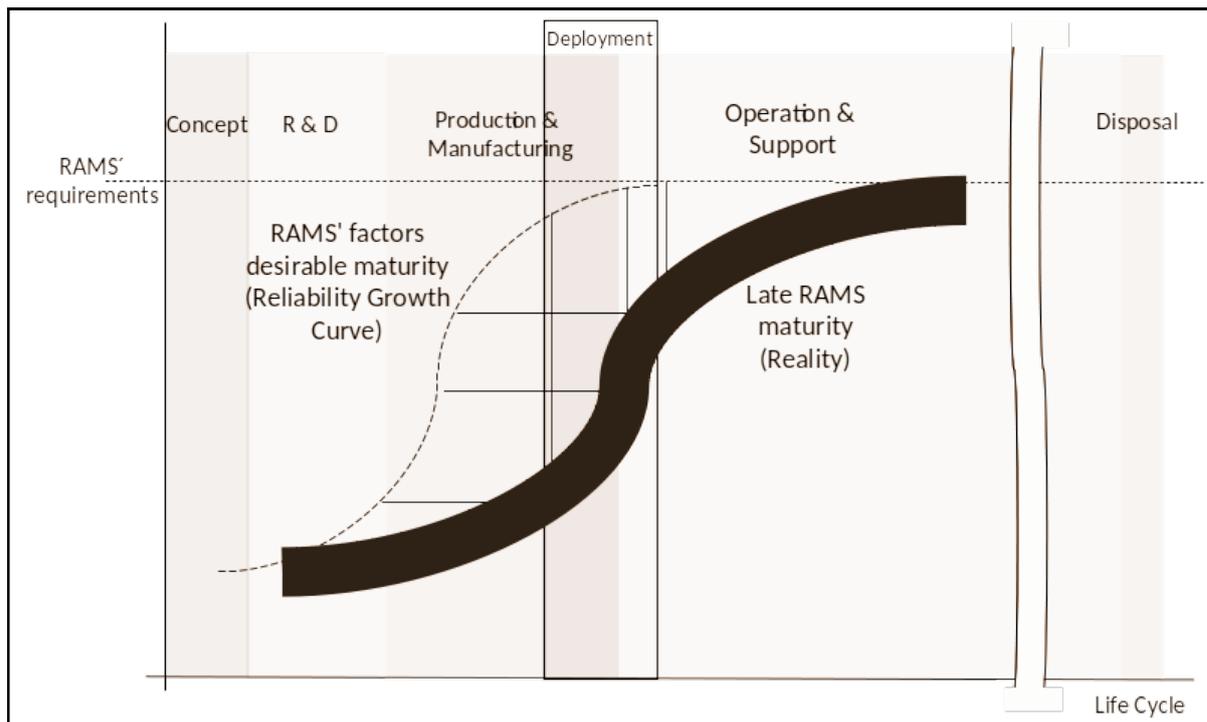


Figure 1 - RAMS' Factors Maturity Development [5]

3. AEROLOGLABTOOL[®] MODULES

In the sequel, there is a straightforward functional description of the AeroLogLabTOOL[®] modules.

3.1. Frequently Asked Questions (FAQ) MODULE

The first module of this version is one traditional Frequently Asked Questions page where the tool presents the main questions about its use and features. The main reason for the FAQ module is to provide formal feedback to queries. Below, the description of the initial set of questions [8].

- What is AeroLogLabTOOL[®]?
- What are the main advantages of this tool?
- How expensive is it to make use of this tool?
- How is the expected environment for this tool?
- Is it possible to run AeroLogLabTOOL[®] offline?
- What are the requirements to run this tool?

- Is there a mobile version of AeroLogLabTOOL®?
- Is AeroLogLabTOOL® suitable for just Defense, or also for Commercial Systems?
- What is the difference between AeroLogLabTOOL® and DAU's IPS roadmap?
- How does the Freemium Stuff work?
- How can I contribute to the AeroLogLabTOOL®?
- Is it possible to donate resources to the AeroLogLabTOOL®?

The FAQ module, as it is now, only contains questions for the initial deployment of the tool. As new questions and answers arise, the module will be reorganized to ease the search for the information needed.

3.2. THE LOGISTICS SUPPORT MATURITY LEVEL ASSESSMENT MODULE (LSMLA)

This module provides the tools to access two main things: the Life Cycle phase where the system is; and the logistics support maturity level of the project. To do that, it compares the project subjected of the analysis to the LSML statement for each ILS element and Life Cycle phase. The results will assess the level of logistics support understanding of the project management and will map the supportability of the system. A comprehensive list of statements is used to analyse the user's project information and to drive the suggestions and the content of the Integrated Logistics Support Plan (ILSP) [8]

3.3. THE LIFE CYCLE PHASE INTEGRATOR MODULE

The integrator is the essence of the AeroLogLabTOOL®. It provides a logistics support information database suitable for each ILS/IPS element and for each Life Cycle phase. It permits the user to design the entire set of concepts, methodologies, tools, tasks, requirements and issues based on the peculiarities of each ILS/IPS Element according to each Life Cycle phase. The module works as a model of the Integrated Logistics Support Plan for every single phase of the development of the support of the system [8].

		Life Cycle Phase Tool				
		Life Cycle Phases				
		Preparation	Development	Production	In service	Disposal
ILS Elements	Maintenance	concepts, methodologies, tasks, requirements and issues				
	Supply	concepts, methodologies, tasks, requirements and issues				
	Manpower	concepts, methodologies, tasks, requirements and issues				
	Training	concepts, methodologies, tasks, requirements and issues				
	Support Equipment	concepts, methodologies, tasks, requirements and issues				
	Technical Data	concepts, methodologies, tasks, requirements and issues				
	Computer Resources	concepts, methodologies, tasks, requirements and issues				
	Facilities Infrastructure	concepts, methodologies, tasks, requirements and issues				
	PHS&T	concepts, methodologies, tasks, requirements and issues				
	Sustaining Engineering	concepts, methodologies, tasks, requirements and issues				
	Design Influence	concepts, methodologies, tasks, requirements and issues				
	Product Support Management	concepts, methodologies, tasks, requirements and issues				
			Integrated Logistics Support Plan			

Figure 2 - ILSP tool Life Cycle Phase Integrator (LCPI)

The output of this module is an Integrated Logistics Support Plan tailored for that specific Life Cycle phase with all the ILS elements addressed and the comments, suggestions and tasks for the next Life Cycle phase logistics improvements.

3.4. THE RESEARCH TOOL

The research tool module works as a research guide for the entire set of topics addressed by the AeroLogLabTOOL®. Figure 3 presents the main databases of the tool. Once the user selects an area of interest, the rest of the lists will provide the options regarding competences accessed by the AeroLogLabTOOL® on each of the remaining lists. The output is a guide including the institutes dealing with the topics of research; the industries that are users of such technology, or interested in; the main researchers of the field; the Life Cycle phase that demands the most; the ILS element most influenced and operators or fleet owners more prone to be interested in such area [8].

The interface consists of seven blue dropdown menus arranged in two columns. The left column contains: 'Areas of Interest:', 'List of Industries:', 'Life Cycle Phase of Interest:', and 'Operators:'. The right column contains: 'List of Institutes:', 'List of Researchers:', and 'ILS Element of Interest:'. Each dropdown menu has a white arrow pointing downwards on its right side. Below the dropdown menus is a grey button with the text 'Matching Tool' in white.

Figure 3 - RESEARCH TOOL INTERFACE

4. STUDY CASES

This part of the text exemplifies how to use the AeroLogLabTOOL[®] according to the peculiarities of each complex system and its actual stage of development. Three cases are presented: one, at the beginning of its Life Cycle, one at the deployment phase, and the other at the end of its Life Cycle. The cases discuss just tools for one ILS Element each due to convenience and room on this text, but the tools and guidance are available for all 12 ILS Elements and all Life Cycle phases ($12 \times 5 = 60$ sets of tools and guidance) [8].

4.1. EARLY PHASES OF THE LIFE CYCLE

The system chosen here is the ATL -100 from DESAER. The ATL-100 is a traditional high-wing twin-engine aircraft, conventional empennage, semi-monocoque structure with a non-pressurized fuselage, rear ramp, non-structural composite parts, landing gear fixed tricycle, 2 ton capacity and range of 1600 km MTOW. It operates from short and rustic airfields, with an average cruising speed of 380 km/h [12].

Since ATL-100 is a system that is on the early phases of the Life Cycle, let's see how it fits to the AeroLogLabTOOL[®]. **Figure 4** presents the first interface with the tool, where the product support manager will have a database of concepts, like CONOPSs (Concept of Operations), CONSUPs (Concept of Support) and CONMNTs (Concept of Maintenance) to explore and derive its own concepts. In the same vein, the tool presents methodologies for the studies required for the development of the entire set of support requirements, including the measures of performance for future evaluations and track. Tools and requirements already used by other users of the AeroLogLabTOOL[®] on the conceptual phase are also available to be considered on the development of the conceptual phase of the ATL-100 Integrated Logistics Support Plan (ILSP). The last set of information presents "best practices" experienced by other users of the tool. The AeroLogLabTOOL[®] is a collaborative framework, so the more users it has, the better the database for others to use on the development of their ILSPs.

The tool is not meant to actually do most of the tasks and analyses, but to guide the program manager and the Product Support Manager how to do and verify it.

Preparation		Life Cycle Phase Tool			
		Concept	Production	In service	Disposal
Maintenance	Requirements	concepts, methodologies, tasks, requirements and issues			
Supply Support	Methodologies	concepts, methodologies, tasks, requirements and issues			
Manpower	Tasks	concepts, methodologies, tasks, requirements and issues			
Training	Activities	concepts, methodologies, tasks, requirements and issues			
Support Equipment	Concepts	concepts, methodologies, tasks, requirements and issues			
Technical Data	Study cases	concepts, methodologies, tasks, requirements and issues			
Computer Resources	Best Practices	concepts, methodologies, tasks, requirements and issues			
Facilities and Infrastructure	Outputs	concepts, methodologies, tasks, requirements and issues			
PHS&T		concepts, methodologies, tasks, requirements and issues			
Sustaining Engineering		concepts, methodologies, tasks, requirements and issues			
Design Influence		concepts, methodologies, tasks, requirements and issues			
Product Support Management		Integrated Logistics Support Plan			

Figure 4 – CONCEPTUAL/PREPARATION AEROLOGLABTOOL® INTERFACE

4.2. DELIVERY OF THE FIRST SYSTEM FOR THE FIRST OPERATOR

Since the system of choice is not on the conceptual phase, it is quite important to assess where the system is regarding its Life Cycle and assess its logistics support maturity. As an example, it is possible that the system is almost been delivered for the first user, but none of the tests to assure the RAMS performances were not even started. In this case, the system would not be mature enough to deploy operations due to the expected poor readiness performances.

The AeroLogLabTOOL® uses the Logistics Support Maturity Level (LSML) assessment module and the ILS Plan (ILSP) tool, as well as the Life Cycle Phase Integrator (LCPI) module to perform these analyses and provide necessary information and guidance to fulfil the logistics support gaps for the case.

Then, and only then, the tools for the specific case are presented. Figure 5 shows the AeroLogLabTOOL® interface providing the set of alternatives for the Supply Support ILS Element. In this case, the Initial Provisioning List (IPL), a comprehensive list of items for the first years of operation must be part of the first system delivered package. The calculations involved required a high level of maturity on the RAMS’ factors, otherwise the IPL is just a guess.

The readiness and capacity of the fleet to keep acceptable levels of availability are totally related to the level of confidence on the RAMS’ factors. AeroLogLabTOOL® suggests a menu of tools to develop the Level of Repair Analysis (LORA), the IPL and some other calculations mandatory for this phase [4].

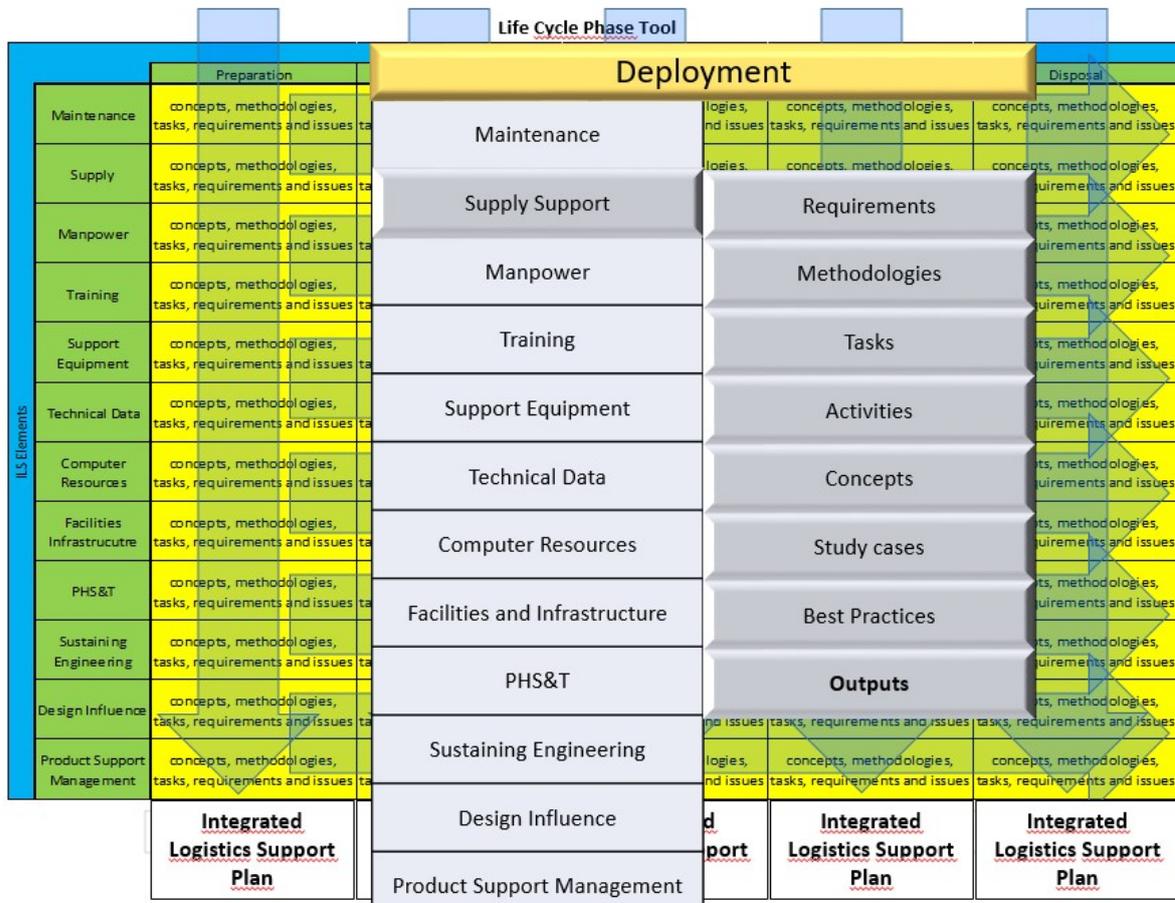


Figure 5 – DEPLOYMENT AEROLOGLABTOOL® INTERFACE

4.3. DISPOSAL PHASE

The final phase of the Life Cycle of a Complex System is the Disposal phase. When the system’s useful life ends, it is necessary to accomplish a series of tasks according to the nature of the system and regulations.

AeroLogLabTOOL® provides guidance and information needed to fill logistical support gaps in case of disposal of a Complex System.

Figure 6 shows the AeroLogLabTOOL® interface that provides the set of alternatives for the Manpower and Personnel ILS element. In this case, human resources management is oriented to perform all planning activities to gradually undo, according to schedule, and transfer human resources abilities allocating those abilities according to other possible demands.

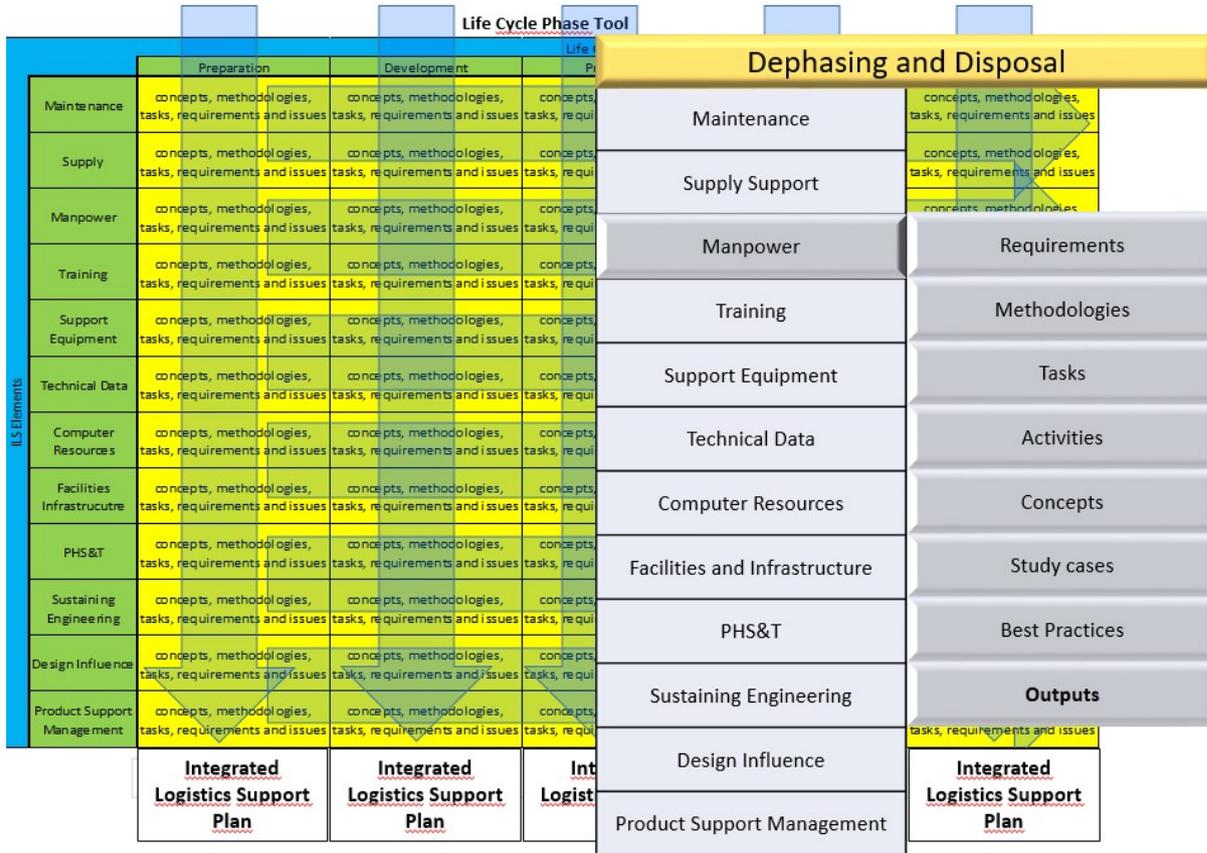


Figure 6 – DISPOSAL AEROLOGLABTOOL® INTERFACE

5. CONCLUSION

AeroLogLabTOOL® is under development and this study presents the concepts involved and some tools already tested and on the way to validation. AeroLogLabTOOL® is free to use and collaborative by concept. New modules can arise according to the knowledge of the various topics addressed by the supportability of complex systems would require.

The AeroLogLabTOOL® idea is, instead of just educating maintainers to become developers, which may not achieve the desired effect, to approach the Training and Education of developers to become (think, understand, act, and develop) systemically support designers. This perspective should lead to Manpower being able to innovate, develop, integrate and manage logistics engineering for Complex Systems, not only just for product development and manufacturing Life Cycle phases, but for the entire Life Cycle up to its exit from the operation.

AeroLogLabTOOL® addresses all twelve ILS elements and Life Cycle phases, providing concepts, methodologies, tools, tasks, requirements and best cases, according to the peculiarities of each Complex System in an iterative and interactive way. It would allow managers and researchers capable of innovation, researching and learning with its partners and offering solid applied and academic research on Logistics Engineering and Maintenance in a complete triple helix environment.

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