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USEFUL LIFE PREDICTION FOR PAYLOAD CARRIER HARDWARE

David Ben-Arieh
Associate Professor
Department of Industrial & Manufacturing Systems Engineering
Kansas State University

ABSTRACT

The Space Shuttle has been identified for use through 2020. Payload carrier systems will be needed to support missions through the same time frame. To support the future decision making process with reliable systems, it is necessary to analyze design integrity, identify possible sources of undesirable risk and recognize required upgrades for carrier systems.

This project analyzed the information available regarding the carriers and developed the probability of becoming obsolete under different scenarios. In addition, this project resulted in a plan for an improved information system that will improve monitoring and control of the various carriers. The information collected throughout this project is presented in this report as process flow, historical records and statistical analysis.

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1. INTRODUCTION

The objectives of the project were defined before the project started in the following way:

> The Space Shuttle has been identified for use through 2020. Payload carrier systems will be needed to support missions through the same time frame. To support the future decision making process with reliable systems, it is necessary to analyze design integrity, identify possible sources of undesirable risk and recognize required upgrades for carrier systems.

Project Summary:

The project resulted in a limited analysis of life expectancy of several carrier systems. Moreover, it established a basis for developing a centralized source of information related to the various payload carrier systems. This information system will be used to monitor and estimate the payload carrier systems ability to meet future mission requirements. While investigating the various carrier systems, the main processes that handle the carriers were analyzed, and a comprehensive historical record of the carriers were developed.

2. PROJECT DESCRIPTION

In order to perform the project, the following steps were identified:

Project Steps:

1. Identify the carrier system items at all locations (KSC, MSFC, GSFC, and JSC) and any commercial carriers (inventory).
2. Identify the various sources of information that describe the various carriers. In each such source the information contents stored has to be identified.
3. Identify the main processes that support the operation of the carriers. These processes include design, analytical integration, configuration management, etc.
4. Develop an integrated view of the information needs of the Payload Carriers Program (building on existing information). This step will lead to a design of a database/documentation system that will store all pertinent data. Based on the system's complexity, determine the level of detail necessary for a useful analysis.
5. For each carrier system, create a useful life profile that identifies expected service life. Historical data, by serial number, will include:
   a. Already assigned useful life
   b. Number of flights
   c. Any failures, damages, accidents
   d. Periods of storage and transportation

e. Test and checkout

f. Maintenance, scheduled or performed only prior to flight

g. Upgrades

Additional information items will be identified in step 3.

6. Using past mission manifests and any known future mission requirements, develop scenarios for more probable, probable, and least probable requirements though 2020.
7. Perform analysis for each system's profile and estimate each system's ability to meet mission requirements through 2020.

3. RESULTS

This section describes the main results of the project. The results are divided into three sections:
1. Analysis of carriers' flight history.
2. Analysis of the processes that handle the carriers.
3. Statistical analysis of probability to exceed the life span of the carriers.

3.1 Analysis of Carriers Flight History

This analysis was performed for the following main carrier types: MPESS, SLP (Space-Lab Pallet, LMC (Lightweight MPESS Carrier) and the Side-Wall carrier also termed Adapter Beam Assembly (handled by GSFC). The historical records of the SLP (also termed Pallet) carrier is presented in Table 1.

Table 1: Pallet Flight History

Table 1a: Flight # 1

Pallet Serial No.	Flight no.	Date	Flight 1 Orbiter	Payload	Time in space
F001/MD001	STS-9	28-Nov-83	Columbia	SL-1	11 days
F002/MD009	STS-35	02-Dec-90	Columbia	ASTRO-1(AFT)	8 days
F003/MD004	STS-51F	29-Jul-85	Challenger	SL-2(3)	9 days
F004/MD002	STS-51F	29-Jul-85	Challenger	SL-2(1)	9 days
F005/MD003	STS-51F	29-Jul-85	Challenger	SL-2(2)	9 days
F006/MD005	STS-41G	05-Oct-84	Challenger	OSTA-3	8 days
F007/MD006	STS-51A	Nov. 8, 1984	Discovery	SRM(WESTAR)	7 days 23 hours
F008/MD007	STS-51A	Nov. 8, 1984	Discovery	SRM(PALAPA)	7 days 23 hours
F009/MD010	STS-61	02-Dec-93	Endeavor	HST SM-01	11 days
F010/MD008	STS-35	02-Dec-90	Columbia	ASTRO-1(FWD)	8 days
E001					
E002	STS-2	12-Nov-81	Columbia	OSTA-1	2 days

E003	STS-2	12-Nov-81	Columbia	OSTA-1	2 days
E004					
E005					

Table 1b: Flight # 2

Pallet			Flight # 2		
Serial No.	Flight no.	Date	Orbiter	Payload	Time in space
F001/MD001	STS-?	Future mission		HST SM-03A*	
F002/MD009	STS-67	02-Mar-95	Endeavor	ASTRO-2 (AFT)	16 days
F003/MD004	STS-46	31-Jul-92	Atlantis	TSS-1	9 days
F004/MD002	STS-45	24-Mar-92	Atlantis	ATLAS-1(Fwd)	10 days
F005/MD003	STS-45	24-Mar-92	Atlantis	ATLAS-1(Aft)	10 days
F006/MD005	STS-59	09-Apr-94	Endeavor	SRL-1	11 days
F007/MD006	STS-64	09-Sep-94	Discovery	LITE-1	11 days
F008/MD007	STS-56	08-Apr-93	Discovery	ATLAS-2	11 days
F009/MD010	STS-82	11-Feb-97	Discovery	HST SM-02	10 days
	STS-67	02-Mar-95	Endeavor	ASTRO-2 (FWD)	16 days

Table 1c: Flight # 3

			Flight # 3		
	Flight no.	Date	Orbiter	Payload	Time in space
F002/MD009	STS-104	12-Jul-01	Atlantis	ISS-7A (airlock)	12 days, 18 hours
F003/MD004	STS-75	22-Feb-96	Columbia	TSS-1R	17 days
F004/MD002	STS-100	19-Apr-01	Endeavor	ISS-6A	11 days, 21 hours
F005/MD003	STS-92	11-Oct-00	Discovery	ISS-03-3A	12 days
F006/MD005	STS-68	30-Sep-94	Endeavor	SRL-2	11 days
F008/MD007	STS-66	03-Nov-94	Atlantis	ATLAS-3	11 days
F009/MD010	STS-*	Future mission		HST SM-03	
F010/MD008	STS-104	24-Jul-01	Atlantis	7A(FWD)	12 days, 18 hours

Table 1d: Flight # 4

			Flight # 4		
	Flight no.	**Date**	**Orbiter**	**Payload**	**Time in space**
F006/MD005	STS-99	11-Feb-00	Endeavor	SRTM	11 days

From Table 1 it is evident that only one pallet flew four missions. The life expectancy of the pallet carrier is fifty missions, thus, there are enough remaining flights within the ten available pallets.

The flight history of the MPESS Carrier is more succinctly represented by Table 2.

Table 2: Flight History of MPESS Fleet

Flight		**MPESS F001**	**MPESS F002**	**MPESS F003**	**MPESS F004**	**MPESS F006**
1	**Payload**	OSTA -2	LFC/ORS	SL-3	OAST-1	MSL-2
	Flight	STS-7	STS-41G	STS-51B	STS-41D	STS 61-C
	Orbiter	Challenger	Challenger	Challenger	Discovery	Columbia
	Date	18-Jun-83	5-Oct-84	29-Apr-85	20-Aug-84	12-Jan-86
	Days is Space	6 days	8 days	8 days	6 days	6 days
2	**Payload**		USMP-1 (Aft)	EOIM-III	EASE/ACCESS	USMP-1 (Fwd)
	Flight		STS-52	STS-46	STS-61B	STS-52
	Orbiter		Columbia	Atlantis	Atlantis	Columbia
	Date		22-Oct-92	31-Jul-92	26-Nov-85	22-Oct-92
	Days is Space		11 days	9 days	8 days	11 days
3	**Payload**		USMP-2 (Aft)	SRL-1	TSS-1	USMP-2 (Fwd)
	Flight		STS-62	STS-59	STS-46	STS-62
	Orbiter		Columbia	Endeavor	Atlantis	Columbia
	Date		4-Mar-94	09-Apr-94	31-Jul-92	04-Mar-94
	Days is Space		14 days	11 days	9 days	14 days
4	**Payload**		USMP-3 (Aft)	SRL-2	TSS-1R	USMP -3 (Fwd)
	Flight		STS-75	STS-68	STS-75	STS-75
	Orbiter		Columbia	Endeavor	Columbia	Columbia
	Date		22-Feb-96	30-Sep-94	22-Feb-96	22-Feb-96
	Days is Space		17 days	12 days	17 days	17 days
5	**Payload**		USMP-4 (Aft)		MFD	USMP-4 (Fwd)
	Flight		STS-87		STS-85	STS-87
	Orbiter		Columbia		Discovery	Columbia
	Date		19-Nov-97		07-Aug-97	19-Nov-97
	Days is Space		17 days		12 days	17 days

Flight		MPESS F001	MPESS F002	MPESS F003	MPESS F004	MPESS F006
6	**Payload**		MSP-1 (Aft)			MSP-1 (Fwd)
	Flight		?			?
	Orbiter		?			?
	Date		?			?
	Days is Space		?			?

The table shows that the MPESS carrier have flown up to six flights. Currently, there are 3 MPESS in existence with a life expectancy of 10 flights. Thus, the fleet of MPESS carriers has a higher chance of becoming obsolete within the planning horizon. This point is further discussed in section 3.3.

3.2 Processes Involved with Carrier Flights

In addition to the discovery of the historical data, the project analyzed several processes that deal with the carriers. The most relevant processes are the general preparation process shown in Figure 1, the Logistic process and Configuration Management process. The later two processes are not described in this report due to lack of space.

The main process of handling the KSC carriers is performed by at least three parties. The design and sustaining engineering is currently performed by a contract supervised by Marshall SFC. The payload ground operations is performed by a contract to Boeing at KSC, while the management of the carrier program is performed by the NASA program. This analysis does not cover the actual loading of the carrier with the payload and loading into the shuttle.

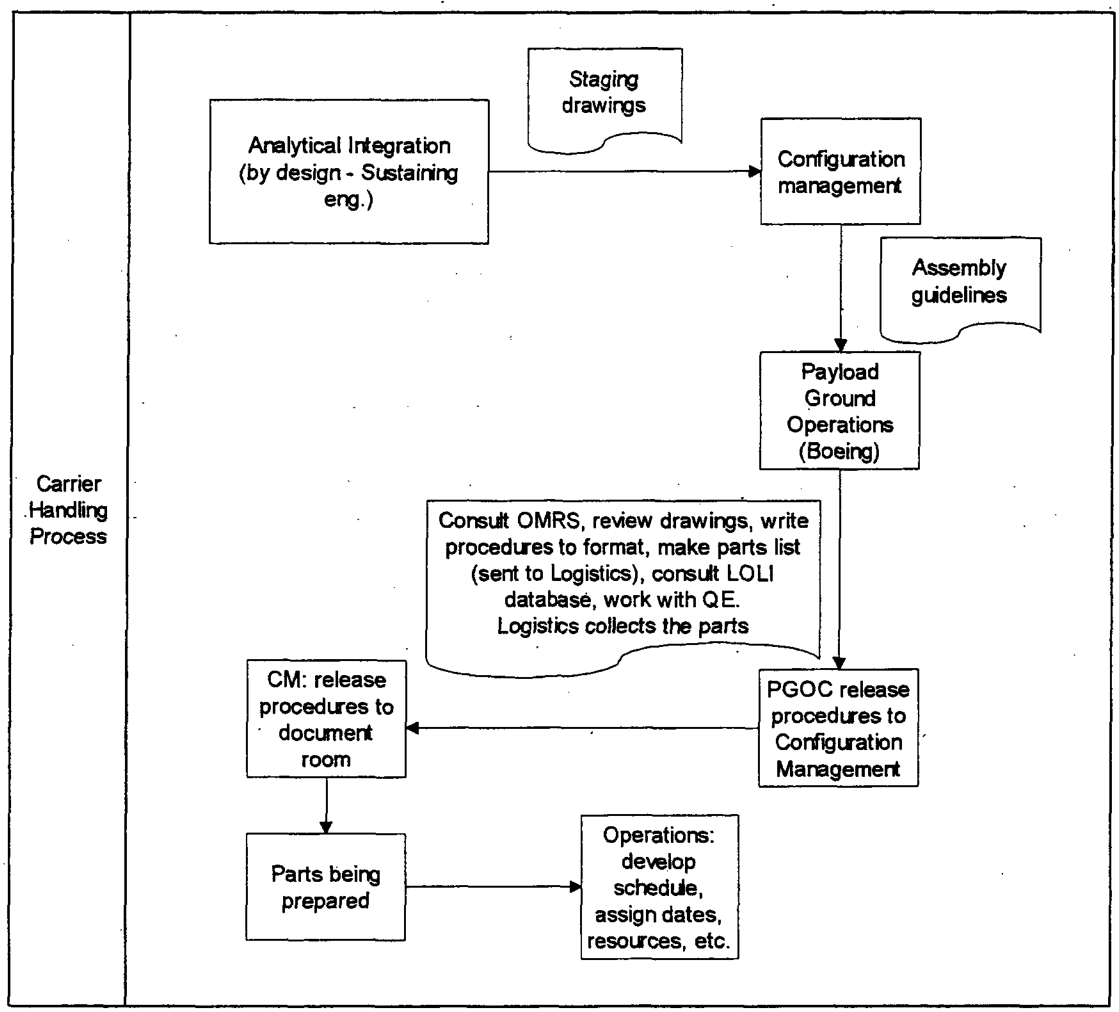

Figure 1: Basic Process of Preparing KSC Carriers

3.3 Statistical Analysis of Carriers Life Expectancy

The statistical analysis of the KSC carriers consists of two parts. The first part considers the "weakest link" within each carrier type. This is the specific carrier (serial number) with the most flights, thus having the shortest expected life span. The second type of analysis is fleet-wide considering al the flights remaining within the entire fleet of each specific carrier type.

The statistical analysis uses the Poisson distribution to model the probability of a given number of flights per year. The Poisson distribution was chosen for the following reasons:

1. It is a discrete distribution very suitable to model a discrete phenomenon such as number of flights per year.
2. The distribution has a moderate variability built-in (the variance is proportional to the mean). This property provides sufficient coverage and safety for the decision maker without exaggerating the range of the results.

The calculations used considered the complement to the cumulative probability expressed as:

$$P(x > K) = 1 - \sum_{k=0}^{K} \frac{e^{-\lambda} \cdot \lambda^k}{k!}$$

Where x is the assumed number of flights and K is the given life span of the carrier. Thus the expression above calculates the probability of the cumulative number of flights *(x)* to exceed the life span of the carrier *(K)*.

The results of the analysis of the first type are presented in figures 2, and 3. The "fleet-wide" analysis is presented in Figures 4, and 5.

3.3.1 "Weakest Line Analysis"

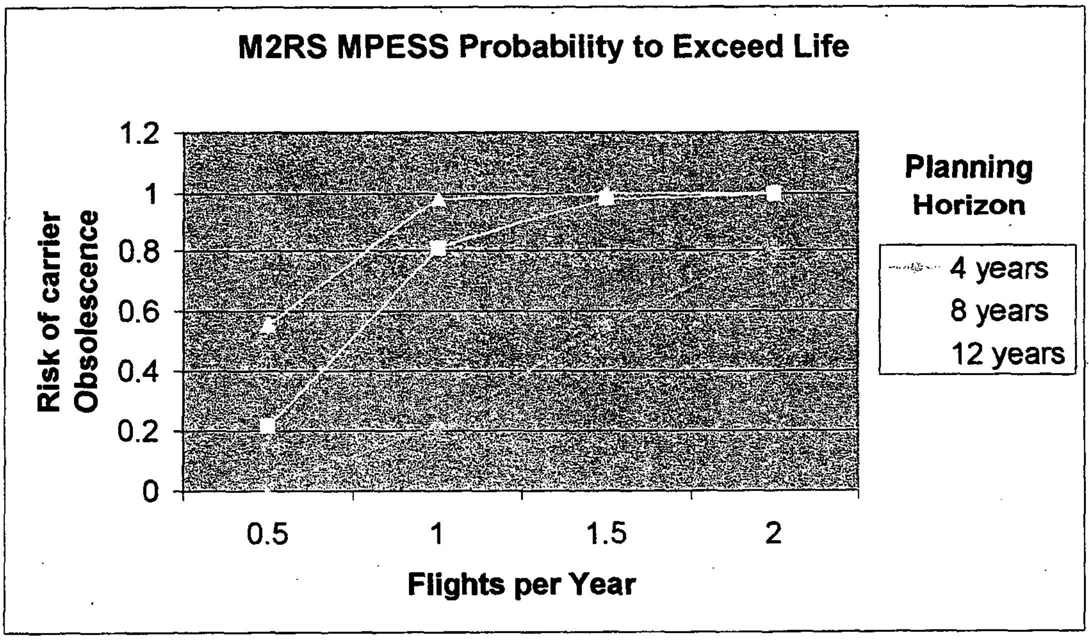

Figure 2: Probability of M2RS MPESS to Exceed Life Span

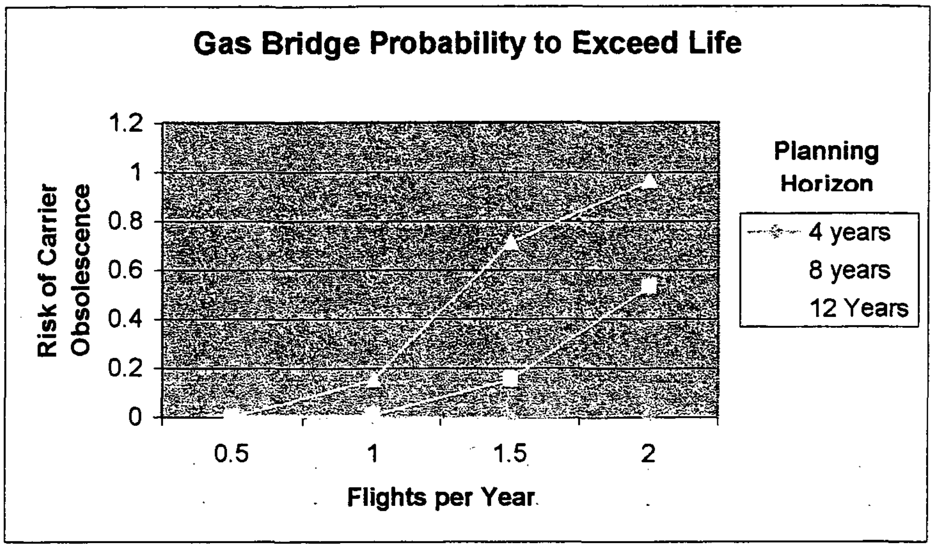

Figure 3: Probability of Gas Bridge to Exceed Life Span

3.3.2 <u>Fleet-Wide Analysis</u>

This analysis is based on the cumulative number of flights that the entire fleet of carriers still has. The figures below show the probability to exceed the life span of the entire fleet. Due to limited space only selected carrier fleets are presented.

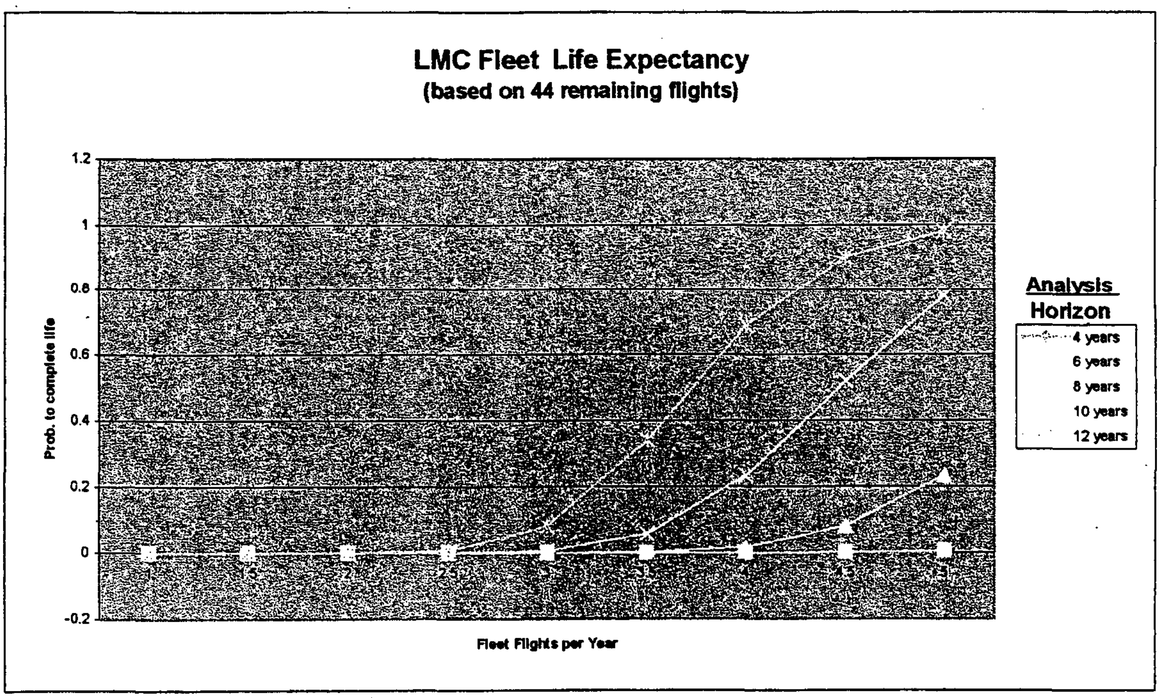

Figure 4: Life Expectancy of the LMC Fleet (three carriers)

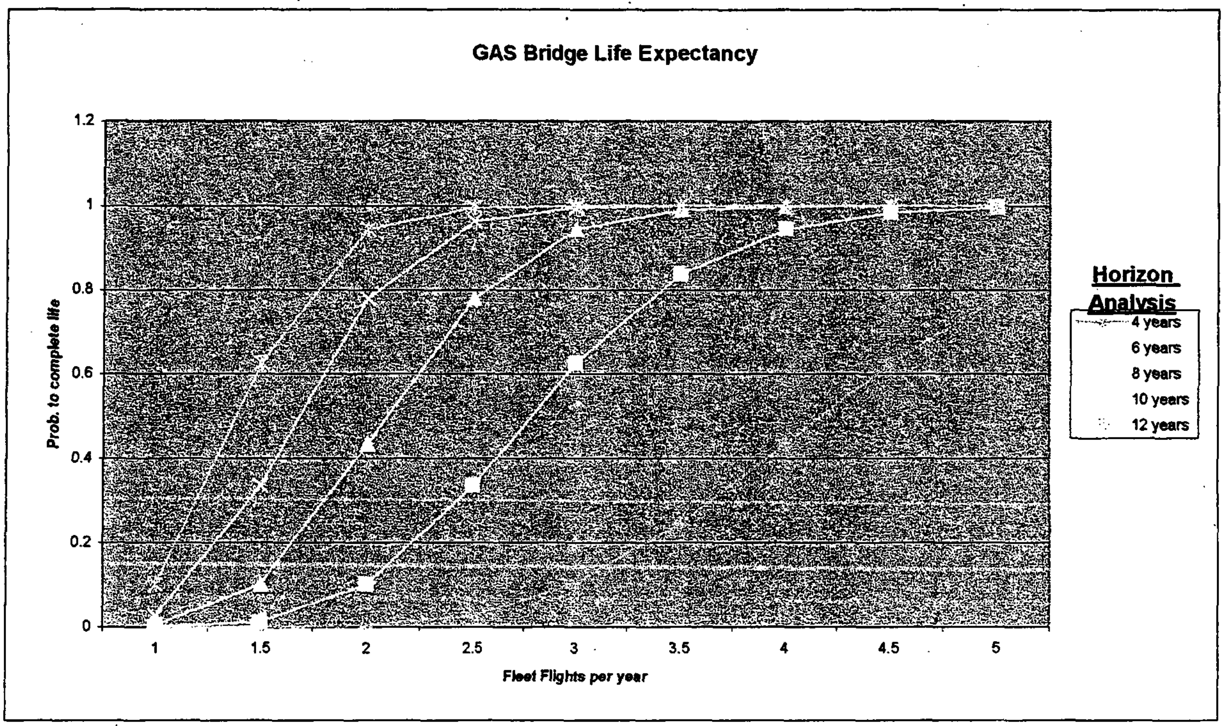

Figure 5: Life Expectancy of the Gas Bridge Fleet (one carrier)

4. SUMMARY

The management of the payload carriers is an intensive activity involving groups across the various NASA centers and dealing with a variety of contractors' organizations. The project identified the main carriers under the Payload Carriers Program responsibility. The only carriers missing so far are the HST (Hubble Space Telescope) and thc Side-Wall carriers handled by JSC.

The project was able to achieve four main objectives. First, record the history of the main carriers. This history includes the flight history as well as major modifications performed on the carrier.
The second accomplishment of the project is the analysis of the main processes pertinent to the carriers.
The third benefit from the project is a statistical evaluation of the probability to exceed the life span of the various carriers, given the assumption that the Space Shuttle will be used until the year 2020.
The fourth accomplishment of the project is the development of a skeleton web-based information system that will allow better monitoring and management of the various carriers. This system was developed and demonstrated to the program management.