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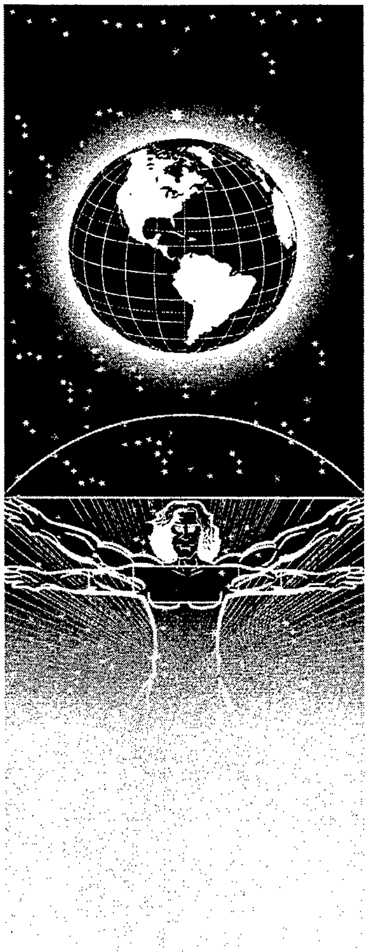

UNITED STATES AIR FORCE RESEARCH LABORATORY

Next Generation Cargo Movement System Analysis

Volume 2: Transportation Research Agenda

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

JAY KIDNEY, Col, USAF, Chief
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This task is second of two research phases conducted to determine future Air Force transportation requirements with the purpose of identifying potential future initiatives. This second phase of the effort analyzed the trends identified in the first phase and selected those critical needs and deficiencies that could be addressed through research within the Air Force Research Laboratory's Sustainment Logistics Branch. It also identified the technologies and research areas with the greatest potential for system benefits and formulated a recommended technology development roadmap entitled Transportation Research Agenda.

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PREFACE

This report documents the results of a study titled Next Generation Cargo Movement Analysis System (Contract Number F41624-98-F-5013) managed by the Air Force Research Laboratory (AFRL), Sustainment Logistics Branch (AFRL/HESS) at Wright-Patterson AFB OH to identify technology development needs and research opportunities in the area of Air Force cargo movement. The task was conducted by Synergy, Inc. from 25 Feb 98 to 5 Oct 98. In this second of two phases, a phased research plan was formulated which recommends research activities that can provide significant benefits to the Air Force and enable critical deficiencies and needs to be addressed through future research and development activities within the AFRL.

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1 INTRODUCTION

Prepared under Government Contract GS-35F-4657G for the Air Force Research Laboratory (AFRL/HESS), this report develops a research roadmap for technologies to support future resource movement requirements. During the preliminary phase of this project a transportation needs analysis was performed based on a literature review, discussion with military and commercial transportation experts, and observation and analysis of military and commercial cargo movement processes and technologies.

The needs analysis is documented in the report entitled Transportation Research for the Next Generation Cargo Movement System Analysis. This Transportation Research Agenda report further develops the needs analysis to identify areas within the resource movement process providing the greatest opportunity for research directed at the future success of transportation.

Starting with a description of the current resource movement process, an analysis establishes the operational requirements for the technology and process definition. Technology and process concepts developed to satisfy those requirements were prioritized based on a set of user-focused metrics to form a list for the research, development, and implementation. The prioritized list was further adjusted to account for interactions among the various concepts to produce the final research, development, and implementation roadmap.

1.1 Background

The future vision of the cargo and passenger movement is driven by the three major factors of mission requirements, operational requirements, and resource restrictions. <u>Mission requirements</u> define the locations to which resources are to deploy and their performance objectives upon arrival. <u>Operational requirements</u> presented by strategic visions such as Global Engagement and Agile Combat Support (ACS) focus on deployment speed necessary to have bombs on target within 48 hours. <u>Resource restrictions</u> limit the funds, equipment, and personnel available within the Air Force to support the deployment mission.

In many ways, the factors are in conflict with one another. As the world's political environment changes, the mission requirements are quickly changing from being relatively predictable and limited in number such that there are fewer planned locations as well as requirements that can occur on short notice. Because of this unpredictability, the prepositioning of resources at locations becomes more difficult. This prepositioning difficulty increased as the resources (funds, personnel, and equipment) became more scarce within the military. These conditions force the Air Force to have increased flexibility and reaction speed to meet mission objectives.

Another condition impacting the selection of future research opportunities relates to the focus and development of current technologies. The physical movement of personnel and cargo has not significantly changed over the last many years. What has changed primarily has been the handling of the information associated with the resources being moved. The information handling capabilities have provided significant improvement in responding to resource movement requirements. The information handling research and development efforts have resulted in significant benefits by facilitating the tracking of personnel and equipment from source to destination.

Because of the information handling advancements, information processing will likely not remain the primary resource movement bottleneck in the far future. Rather, the physical handling of the resources as performed today is already identified as a processing bottleneck that will worsen in the future if not addressed in the near future. Thus, while the goal of the analysis is to look at all aspects of the resource movement process, the primary focus is the physical movement of personnel and equipment which may include certain unique aspects of information processing.

Figure 1 presents the combined groupings of formal and informal needs and deficiencies presented in the document entitled Transportation Research for the Next Generation Cargo Movement System Analysis. The percentages are based on a total of 243 identified needs and deficiencies.

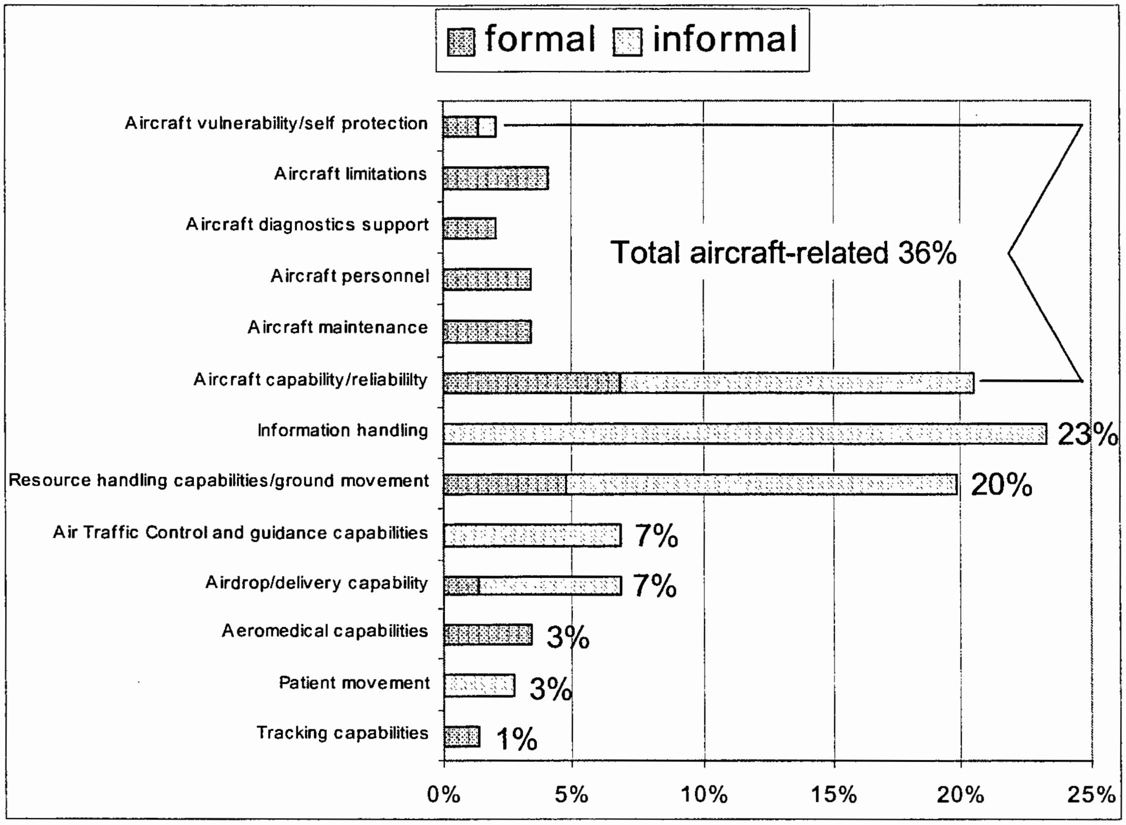

Figure 1. Summarized Grouping of Formal and Informal Transportation Needs and Deficiencies

Figure 2 represents the further aggregation of the groupings' operational goals. Specifically, ATC and tracking capabilities are a subset of information handling, and airdrop is a type of cargo handling capability, while aeromedical capabilities are a subset of personnel handling capabilities. Regeneration of the above list based on these assumptions produces the following list and aggregated values, thus identifying the top three areas for improvement.

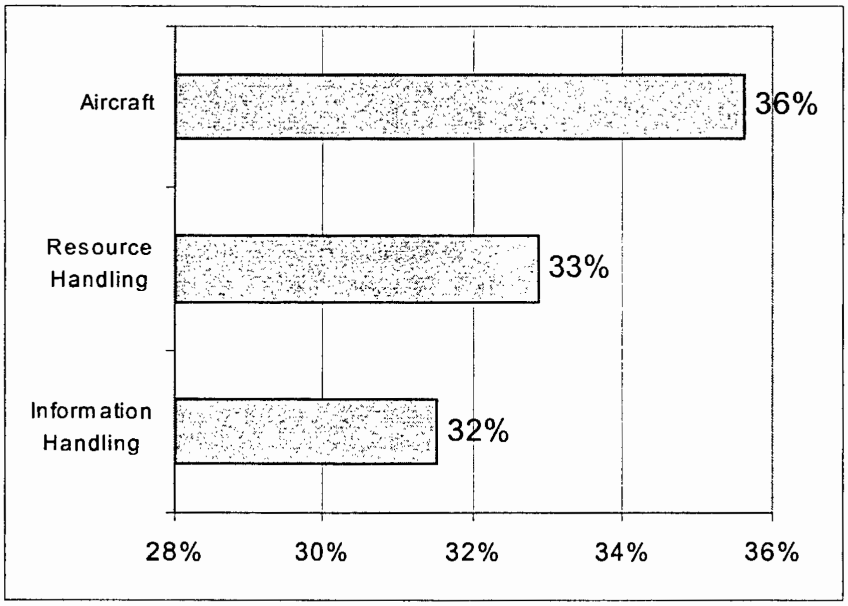

Figure 2. Transportation Needs and Deficiencies
Aggregated into Three Major Groupings

2 Cargo Movement Overview

The three major transportation areas for improvement just established from three of the four facets or levels comprising resource movement as presented in Figure 3. The one level not identified is the process definition itself. These levels must be effectively coordinated to successfully accomplish the goal of moving resources from one point to another. The process definition represents the steps involved in moving resources. The basic goal of this process has remained constant for many years, and will continue to remain constant for years to come, even though specific movement steps will change as technologies are changed. Because the successful accomplishment of the process represents the final goal of resource movement, the process definition forms the focal point against which users measure the success of resource movement. The Material Handling Equipment (MHE) level identifies the technologies used to implement the resource movement process at the deploying, enroute, and reception sites. Information handling is an integral part of all aspects of the resource movement process, and specifically provides resource tracking and the overarching structure for resource control. Transport aircraft are the technologies, such as the C-130, C-141, and C-17 providing the transfer capability from source to destination.

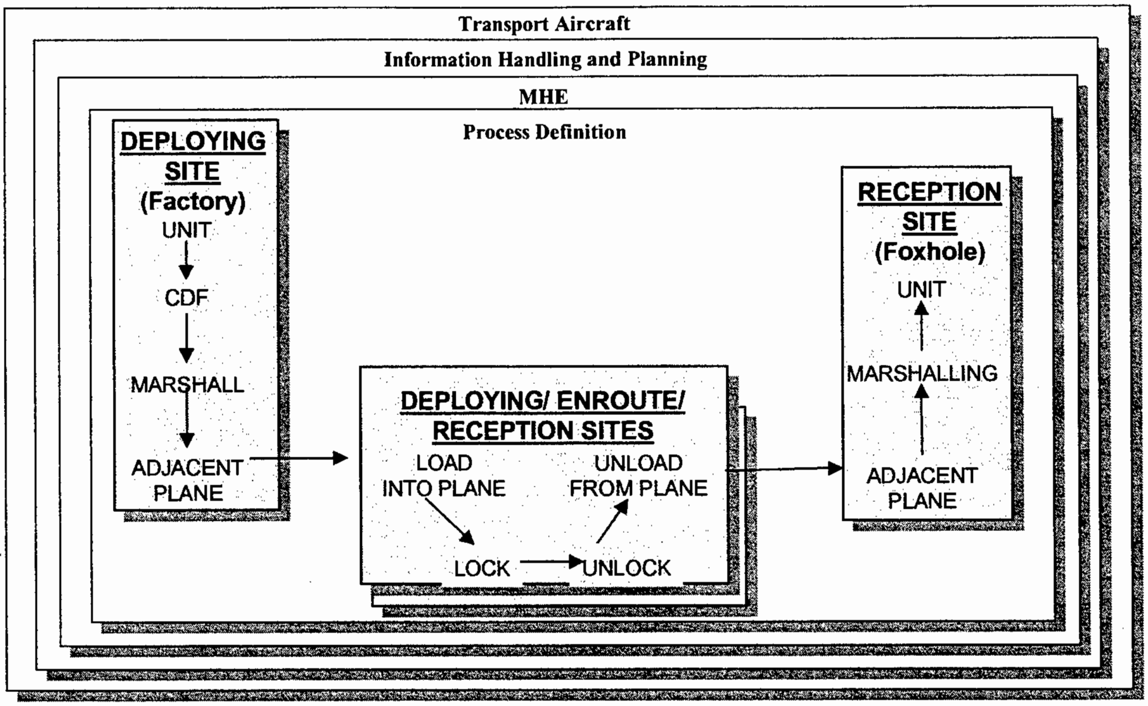

Figure 3. Cargo Movement Process Represents the Driving Requirement

The cargo movement process cannot be accomplished by one technology. Rather, a set of technologies must function as an integrated system or team. Functioning as part of a system, each technology provides added value to process performance. Therefore, the evaluation will be performed for a total system perspective as well as an individual technology based on how well the technology supports the system performance.

The process as represented in Figure 3 defines the steps performed in today's cargo movement efforts. For the LOG-AID program, an analysis of the wing-level deployment process identified a number of Deployment Process Improvements (DPIs) from the receipt of the deployment tasking at the base until the deploying resources were loaded on the transporting aircraft. When implemented, DPIs will streamline the process by removing or reducing the number of steps between the unit and the transporting aircraft. For example, more effective cargo preparation by the unit reduces and may eventually eliminate the need to process increments through the Cargo Deployment Function (CDF). Coupling this improvement with more accurate information on transport aircraft type and schedule allows for direct cargo movement from the unit to the aircraft, thus eliminating or at least reducing the need for the marshalling area.

This change in processing steps increases the need to move cargo quickly and efficiently from the unit to and into the aircraft. These same conditions also exist at the aerial ports and the reception sites. Inherent in the need to move cargo quickly is the requirements on MHE to support the increased speed requirements, both as individual MHE and as an integrated system of MHE.

2.1 Process Definition and MHE

The cargo movement process is represented by three major steps. Step one is the preparation of the resources at the source or deploying site. Step two is the loading and unloading of the transport aircraft, occurring at deploying sites, and possibly at an intermediate aerial port. Step three is the unloading at the destination site. While the basic cargo movement process remains constant, the MHE technologies selected to implement the process and the integrated application of those technologies can significantly impact the effectiveness of the movement process.

2.1.1 Preparation at the Source

Deployment site preparation includes the identification of resources for deployment, the organization of the cargo resources into increments, and the preliminary weighing and measuring of those increments. The increments are placed in a holding area while transportation is notified that the increments are ready for movement from the unit to the CDF.

For rolling stock increments, the unit usually moves the prepared increment to the CDF, and then to the marshalling area. Palletized and containerized increments are prepared and normally set aside awaiting base transportation to accomplish the transport to the CDF. For normal sized increments, and assuming the distance from the unit to the CDF is not too great, base transportation uses forklifts for the transfer. For oversized increments or for longer transfer distances, a combination of forklifts and trucks are used for transfer to the CDF.

Within the CDF, forklifts provide the primary support for moving the increments around as necessary. Following the CDF check, forklifts provide the primary means of moving the increments to the marshalling area.

Upon arrival of the transporting aircraft, increments are moved from the marshalling area to the aircraft. Rolling stock is either driven or pulled to the aircraft position. Non-rolling stock is moved in one of two ways. One is by using a forklift to move the increment to the aircraft. Another is to use a forklift to load the increment onto a K-Loader in the marshalling area and the K-Loader transfers the increment to the aircraft.

2.1.2 Unloading and Loading at Home Station/Aerial Port

Loading the increments into the aircraft involves two primary steps. Step one moves the increment from the ground to the aircraft floor. The approach used depends primarily on a combination of the increment and aircraft type. For rolling stock, the increments are driven on, pulled on, or placed on a K-Loader and raised into the aircraft. Pallets and containers are placed on the K-Loader and raised into the aircraft. Step two moves the increment into place and fastens in the aircraft for safe transport. Rolling stock and containers are fastened using a chaining technique while pallets lock into place using the aircraft's pallet locking system.

If an aerial port stop is required prior to going to the final destination, the increments are unloaded from the aircraft and moved into a marshaling area. The same loading process is again performed into the aircraft taking the increments to their final destination.

2.1.3 Unloading at Destination

Upon arrival at the destination or reception site, the increments are unloaded from the aircraft and moved to the designated unit position. At times, the move to the designated unit may include a stay in the marshalling area if immediate transfer to the unit is not available.

Depending on the situation at the reception site, the manner in which the unloading process occurs can vary. When time and conditions permit, the preferred approach is the standard unloading process. When time is short and conditions are threatening, combat unload may be used, and if landing the aircraft is not possible, airdrops may be used.

Standard unloads require the aircraft to land, park in a designated area, and shut the engines off. MHE are then used to perform the unload process. Combat unloads focus on getting the aircraft into and out of the reception site as quickly as possible. The process to accomplish this unloading takes on a number of variations. One variation is to park the aircraft in a designated area and perform the unload process without shutting off the engines. The same approach may occur but while on the runway. Or the increments may be unfastened from the aircraft such that when the aircraft moves forward quickly, the increments are extracted from the back of the aircraft. Airdrops require the unfastening of the increments for the aircraft and using chutes, pulled from the aircraft and lowered into the landing zone.

K-Loaders, forklifts, and trucks provide the primary support for unloading and must be brought in on previous chalks or prepositioned at the destination. For combat unloads, the increments are left on the apron or runway as they are unloaded. Once unloaded, a combination of support equipment pickup and distribute the increments to the designated units. The distribution process may include a stay in a marshalling area.

2.2 Transport Aircraft

Transport aircraft represent a significant investment and the most valuable resource involved with the resource movement process. As was determined through the needs analysis, the group of deficiencies and needs associated with transport aircraft was the largest. These improvement issues included the development of new aircraft, increased maintenance and reliability of existing aircraft, and increased utilization of existing aircraft. The scope of this program, however, does not include ideas directly targeted at transport aircraft. Because of the importance of the transport aircraft, the capabilities of the aircraft present a number of considerations for the resource handling research analysis.

The resource movement capabilities designed into the aircraft provide a significant impact to MHE requirements. While the various aircraft are of different design and size, the resource handling capabilities built into the aircraft are basically the same. Namely, rolling stock is positioned and chained down while pallets are rolled into position and locked into place. The use of commercial aircraft to support military requirement dictate common loading and unloading capabilities between military and commercial aircraft as well as common increment locking capabilities.

Reliance on commercial airlift leads into another consideration that is further exacerbated by limited funds for the military to purchase new transport aircraft. Specifically, funds are not readily available for the military to purchase aircraft with military-unique carrying capabilities. Rather, the military is being driven to purchase aircraft designed towards the commercial market. The advantages of this are the military can take advantage of commercial Research and Development (R&D), and receive a lower unit cost because of the larger purchasing community. This use of commercial-like aircraft and the cargo technologies being developed, demonstrated, implemented, and proven in the commercial world is gradually forcing the military resource movement process to emulate that of the commercial world.

2.3 Information

Information is a critical component of transportation and consists of four major functions as represented in Figure 4. As the focal point, the transportation process is the source of information for all decision-making and process control directives. As the transportation process occurs, the status collection and tracking function collects information for both the resources being deployed and those supporting the deployment. Within the scheduling function, user requirements are overlaid onto the status information to produce a suggested schedule for the movement of deploying resources as well as a suggested schedule for the placement of support equipment. Refinements to the suggested schedule are provided to the decision support function prior to its distribution to the command and control functions. Through the command and control, the approved schedule drives all deployment activities. The comparison between the schedule and actual movement results from a comparison between the status collection and tracking function and the command and control function. Changes in user requirements and the lack of support equipment triggers adjustment to the schedule, resulting in an ever-changing goal for the deployment process. The tight interactions among the various components of information handling clearly highlight the need for a coordinated set of information processing capabilities.

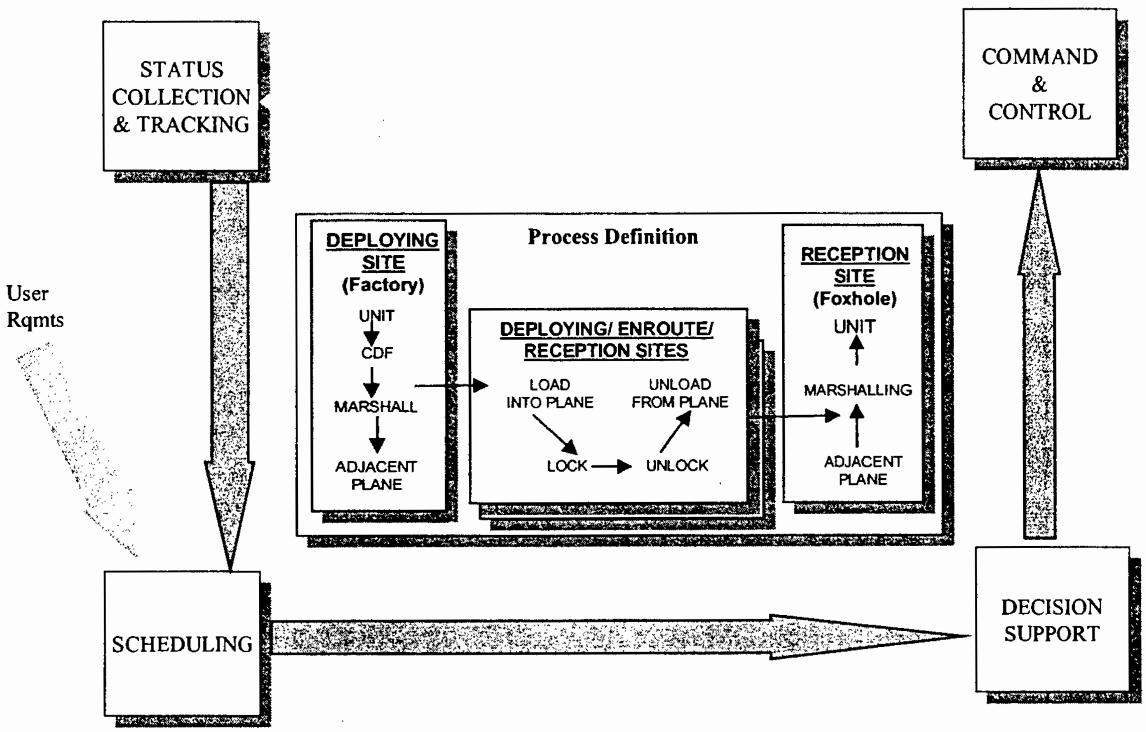

Figure 4. Information Process Cycle

2.4 Process Analysis

Because of the dependent interactions existing among the four major functions, there is required an analysis capability that evaluates the effectiveness of the overall information handling process. This analysis capability identifies the location of the bottlenecks within information processing as well as the magnitude of their impact on the overall process. Through this analysis, the functional requirements along with the specifications for the new technologies will be identified.

2.5 Comparison with Non-Air Force Cargo Movement

While this report focuses on improving the Air Force resource movement capabilities, information from the other services and the commercial environment brought in perspectives and ideas from those organizations. The commercial sources of information included Emery Worldwide, FedEx, United Parcel Service along with companies for truck, railroad, and ship transportation. These information exchanges provided insights into the processes and technologies implemented by these organizations, the problems being encountered, and their visions for the future as related to the movement of cargo.

In summary, many similarities exist among these various modes of transportation, starting with the cargo movement process. Specifically, cargo items are prepared and grouped based on destination, mode of transportation, and assignment to the transportation vehicle. Following the preparation, the loading plan is developed, the items moved to the transporting vehicle, and loaded into the vehicle. At the destination, the cargo is unloaded and moved to its owner, with a possible stay in a holding area if immediate delivery to the owner is not possible.

Except for the actual means of transportation, many similarities exists among the MHE used to support the move. All modes of transport use forklifts, tow vehicles, and ramps. Commercial air transport uses double platform loaders, which are functionally similar to the military K-Loader. Railroads and trucking rely on ramps, while railroads, ships, and trucking rely heavily on hoists. Similar also between the Air Force and commercial cargo movement is the use of intermodal transportation. Containers carried by trucks are loaded onto rail cars and ships, with containers including the actual truck trailers.

Information tracking is critical to all modes of transporting, with the biggest difference being the two levels of detail at which the tracking occurs. Most carriers track resources being moved at the container or pallet level since most resources moved in the commercial world are received by and delivered by the transporter at the container level. In contrast, carriers such as Emery Worldwide and FedEx are more like the military in that they receive individual items from which are built increments. Because of their operational scope, these transporting organizations track items at both the increment and individual item levels.

Two obvious differences between Air Force and non-Air Force cargo movements are the use of containers and ground support equipment. In general, commercial transporters rely heavily on containers while the Air Force uses pallets to move a large percentage of its cargo during airlift. Commercially used containers vary greatly in size, ranging from the smaller containers used by Emery to semi-trailers transported by trains and ships.

The other obvious difference between Air Force and non-Air Force cargo movement is the requirement for deployability. Commercial transporters load and unload out of stationary facilities, therefore, the design of their facilities focus on the fast, efficient movement of the cargo. In contrast, the deployment requirements dictate that the Air Force have loading and unloading capabilities that can themselves be loaded, transported, unloaded, and readied for use with minimal impact on the deployment schedule.

3 Analysis

For each of the groups discussed previously, research opportunities are identified and ranked based on their impact on transportation requirements.

3.1 Cargo Movement Analysis

The MHE, the cargo itself, and cargo movement process form a system for moving cargo from one location to another. Measuring movement effectiveness must be done at two levels. The ultimate level is the effectiveness of the overall system. Within that ultimate measurement is the effectiveness measurement of MHE, cargo, cargo movement process as components comprising the system. This approach allows for the identification of the weakest links in the movement process so that improvements can be addressed at that link.

The evaluation begins by identifying the characteristics of MHE and cargo and relationships among those characteristics. The identification and application of user-oriented metrics then measure the effectiveness of various MHE and cargo characteristics combinations. The identification of optimal integration of MHE and cargo characteristics then provides the basis for selecting specific MHE concepts to satisfy the requirements, thus identifying potential MHE research opportunities

3.1.1 Cargo Movement Characteristics

An analysis of the process briefly described above identifies important characteristics for consideration in the selection and development of MHE. The first characteristics relate to the MHE and cargo, the second characteristics relate to how the MHE and cargo fit into the process.

As represented in Figure 5, two categories of MHE exist to move two types of cargo. For MHE, integrated MHE, to include pallets and containers, becomes an integral part of the mission cargo being moved, therefore not significantly increasing the deployment footprint. In contrast, support MHE, to include K-Loaders and forklifts, remains physically separated from the cargo while it moves cargo items or cargo integrated with MHE. Because it does not become part of the deploying mission resources, the support MHE becomes standalone increments when deployed, thus taking up space needed for mission resources and therefore extending the deployment timeline and increasing the deployment footprint.

For cargo, rolling stock has wheels allowing it to be moved on its own if powered or pulled by powered rolling stock or support MHE if not powered. Bulk cargo is usually packed onto integrated MHE and moved by support MHE.

Table 1 summarizes the advantages and disadvantages of deploying resources.

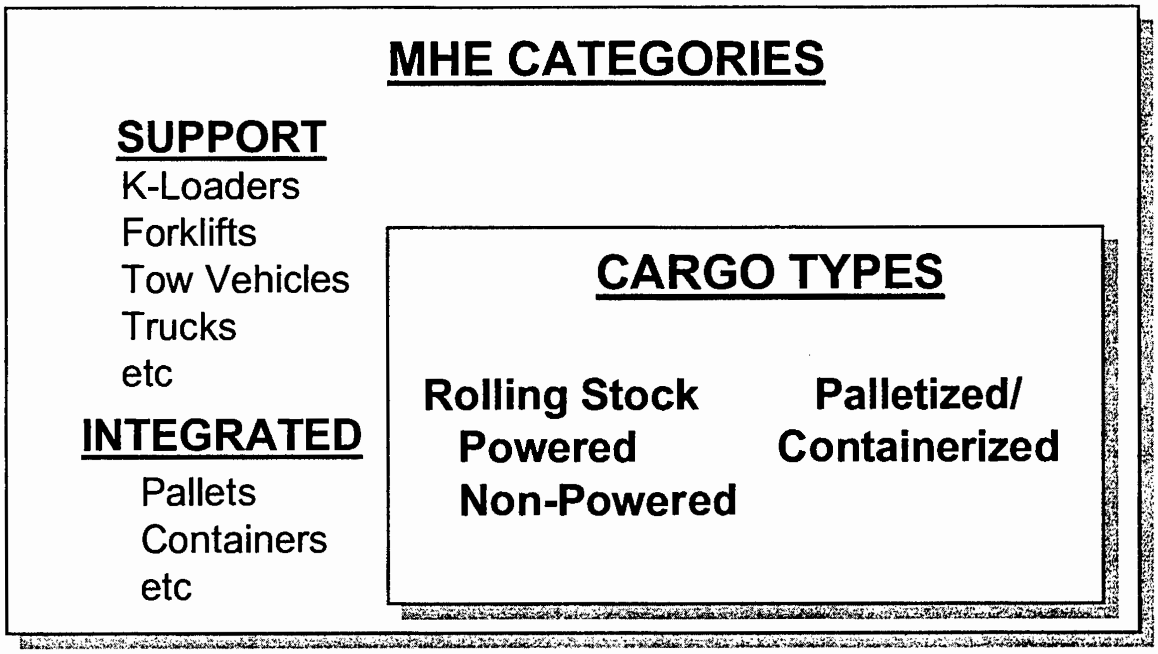

Figure 5. Relationship between Cargo and MHE

Table 1. Advantages and Disadvantages of Current Technologies

MOVEMENT TECHNOLOGY	ADVANTAGES	DISADVANTAGES
Palletized Cargo	• Minimal development and maintenance cost of basic pallet technology • Fast loading into the aircraft • Fast locking into the aircraft • Minimized space required in transporting empty pallets	• Skill level required in packing • Problems existing in securing the items with netting • Secondary equipment needed to move the pallet
Rolling Stock	• Self powered or minimal pull capability to move the increment through the deployment and reception site process • Limited potential for frustrating the increment	• Slow process for securing the increment in the aircraft.
Container	• Fast packing • Limited concern in packing except in the placement or hazardous materials. More of a "fit it in" approach can be applied than following more specific placement rules used for pallets. • No concern in building to the correct size to fit into the aircraft.	• Usually fastened onto pallets for transporting, thus benefiting from palletized cargo but requiring two technologies • Support MHE needed to move the increment. Depending on the container, the support MHE varies widely from fork lifts to specialized trucks.

Relating the characteristics of the cargo and MHE to the process identifies an important processing characteristic. While on the ground, rolling stock provides the most efficiency since it can be moved quickly and with minimal MHE support. Once in the aircraft, the optimal efficiency transfers from rolling stock to pallets because pallets can simply be locked into place while rolling stock requires the laborious process of being chained down. In a similar manner, the cargo characteristics impact the unloading and distribution process. There exists, therefore, a change in technology effectiveness when going from ground movement to aircraft loading as indicated in Figure 6. Establishing an effective and efficient cargo movement capability must therefore focus on addressing the processing characteristics, specifically the technology transition between ground movement and aircraft loading.

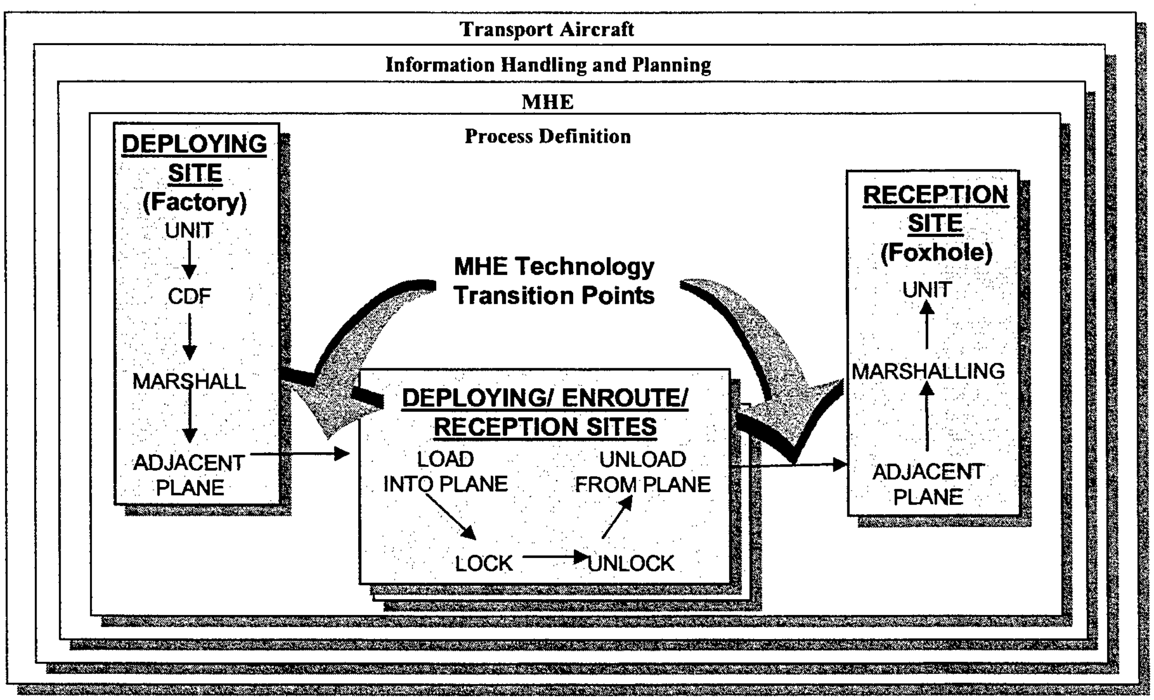

Figure 6. Transition Points in the Process

This discussion highlights a couple of important issues. One issue is that reducing or eliminating support MHE would significantly reduce the deployment footprint. This is especially true for the K-Loaders with the general rule being three K-Loaders required for each aircraft being unloaded. The number three exists because two are actually used but one is usually not operational. Therefore, if two aircraft are to be unloaded simultaneously, five to six K-Loaders must be deployed to the site.

Another issue is the duplicate use of MHE. To optimize the efficiency of the MHE deployed, any secondary use made of the MHE would increase its value as a deployable item and help offset the value of the space it used for deployment. For example, a wheeled MHE item such as pallet dollies facilitates ground movement of pallets. When not used to move pallets, various types of structures placed on the dollies would provide the dollies with other functional capabilities such as personnel movers, trailers for general movement of materials, etc. These and more factors are considered in the generation of metrics discussed in the next section.

3.1.2 MHE and Process Evaluation

Improving the movement of resources using MHE does not necessarily require the development of new MHE. Rather, processing improvements could be realized in optimizing the use of existing MHE. Currently, forklifts, K-Loaders, and pallets represent the backbone of the cargo movement capability. For various reasons, the coordinated use of MHE varies among sites. At some sites, forklifts transport cargo from the marshalling area to the aircraft where it is placed on the K-Loader for transfer into the aircraft. At other sites, forklifts load increments onto the K-Loaders in the marshalling yard and the K-Loaders transport increments between the marshalling yard and the aircraft.

The evaluation of the MHE and process addresses these variations in use and incorporation of new technologies using two approaches, one focused on processing time and other on the effectiveness of the MHE and process system. The results of the two are then combined to provide the final analysis results for the scenarios. Analysis of scenario results helps identify the weak points within the process.

3.1.2.1 Metrics

Table 2 presents a set of user-focused metrics for measuring transportation technology and process effectiveness that are used by or evolved from those metrics used within the deployment and transportation community. Included with most of these metrics is included a reference back to the AEF metric.

The application of these metrics must consider transportation technologies individually and as being one element of an integrated system of transportation technologies. Individual technologies may provide effective stand-alone capability for a part of the transporting process but may not interface well with other technologies used to complete the transporting process. Therefore, the eventual selection of transportation technologies for research will be strongly influenced by its ability to integrate into a complete transporting capability.

Table 2. Metrics for Measuring MHE System Effectiveness

TRANSPORTATION METRIC	DEFINITION	AEF METRIC
Speed of movement	The time required to move an increment from one location to another within the same base. Time of movements – Minutes	Response time from execution order to first employment
Number of transfers among technologies, with the ground considered a technology	The times an increment is transferred from one technology another, assuming, each transfer requires some type of support technology. Integer number	Response time from execution order to first employment
Number of personnel required	The number of persons required to effectively transport an increment from unit generation to unit usage at the reception site. Integer number	Response time from execution order to first employment
Deployment footprint of empty MHE	The airlift space required measured in terms of the spaces required when the increment is transported empty. Real number	Lift required per mission aircraft
Operational footprint	The airlift space required measured when the MHE is filled. Small = 1 Medium = 2 Large = 3	Lift required per mission aircraft
Number of times MHE positioned against aircraft	MHE, such as the K-Loader, often transports the increments to the aircraft as well as transferring the increments into the aircraft. This number is based on the number of increments the MHE can deliver at one time. Integer	Response time from execution order to first employment
Deployment footprint of increment	The increment footprint to include the MHE required to deploy to support the movement at the reception site. Integer	Lift required per mission aircraft

TRANSPORTATION METRIC	DEFINITION	AEF METRIC
Efficient us of aircraft floor space	The percentage of aircraft floorspace used versus that available.	Lift required per mission aircraft
Multiple use of MHE technologies	Can deployed MHE be used for other purposes at the reception site? Yes = 1 No = 2	Lift required per mission aircraft
Use of technology at both deploying and reception sites	The same usage of MHE at both locations minimizes the variations that must be considered by the transporting personnel. Yes = 1 No = 2	Lift required per mission aircraft
Technology operability with other services and commercial capabilities	Common usage of technology among all transporting services minimizes the restrictions placed on the deployment planning and execution, and provides additional flexibility. Yes = 1 No = 2	Lift required per mission aircraft
Mean time between failures	The reliability and maintainability is the comparison of operational versus maintenance time and the length of time between the down times. Low = 1 Medium = 2 High = 3	Lift required per mission aircraft

3.1.2.2 Scenario Definition

To address varied combinations in MHE and process implementation a set of scenarios were developed. While there are numerous scenario possibilities, six have been selected to demonstrate the analysis concept while providing sufficient results to justify the MHE research suggested. The first four scenarios represent variations in the use of MHE technologies currently used. Scenarios five and six incorporate technologies that either exist and are not used within the military or are being proposed as new technologies. These scenarios are listed below and included in Table 4. Because these scenarios are for illustrative purposes rather than a full detailed analysis, these scenarios address only the deployment portion of the cargo movement and the information used is based on information extracted from the LOG-AID analysis effort.

Scenario 1: Palletized Increment with the K-Loader used for transport
- Forklift moves increment to CDF and then to the marshalling area
- Forklift loads increment onto K-Loader in the marshalling area
- K-Loader transports the increment to the aircraft
- K-Loader is positioned against the aircraft

Increment is transferred into the aircraft
Pallet is locked into place

Scenario 2: Palletized Increment with the forklift used for transport
Forklift moves increment to CDF and then to the marshalling area
Forklift moves increment from CDF to the aircraft
Forklift loads increment onto K-Loader
K-Loader transfer increment into the aircraft
Pallet is locked into place

Scenario 3: Rolling Stock (Non-Powered)
Tow vehicle pulls increment to CDF and marshalling area
Tow vehicle pulls increment to aircraft
Increment pushed or winched into aircraft
Increment chained fast

Scenario 4: Rolling Stock (Powered)
Increment moves to CDF and marshalling area
Increment moves to aircraft
Increment is driven or winched into aircraft
Increment chained fast

Scenario 5: Pallet dollies to transport pallets
Pallet dollie train pulled to CDF and marshalling area
Pallet dollie train pulled to aircraft
Pallets individually transferred to K-Loader
K-Loader transfers increment into aircraft
Pallet is locked into place

Scenario 6: Wheeled pallet to transfer cargo
Pallet train pulled to CDF and marshalling area
Pallet train pulled to aircraft
Pallet raised into aircraft with a ramping system and wheels raised
Pallet locked into place

The technologies included in the scenarios are the forklift, K-Loader, commercial loader, tow vehicle, pallet dollies, wheeled pallets, and roller coaster ramp. The forklift and K-Loader are existing military MHE. The commercial loader provides the same functionality as the K-Loader but has two platforms with powered rollers. One platform moves vertically to transfer increments from ground level to the upper platform and the upper platform provides for the transfer into the aircraft. Tow vehicles include almost any type of vehicle with pulling capability, to include such things as small tractors, trucks, and forklifts. Pallet dollies are used extensively and successfully in the commercial environment. One of the main problems with their use in the military is the height incompatibility between commercial dollies and K-Loaders. Because of this, forklifts are required to transfer between the dollies and K-Loaders. Pallets will remain a primary integrated MHE technology. Adjusting the characteristics of the pallet by adding retractable wheels minimizes the need for support MHE during for ground maneuvering while maintaining use of the aircraft pallet locking system. The loading/unloading ramp supports and facilitates the transition between the aircraft and the ground by allowing for the raising and lowering of pallet wheels with no movement delay.

3.1.2.3 Scenario Times

Times to accomplish the move were assigned to the processing steps to represent the transport speed of the technology. Baseline times for the scenario 1 process were extracted from the "As-Is" LOG-AID simulation. These baseline times were collected from discussions with users and observations of deploying activities. Verification of the baseline times came through reviews with functional area experts and exercising of the model in that the total processing times were consistent with operational deployment times. Times for the scenarios 2 through 6 were then estimated based on those baseline times and are recorded in Table 3. Because the scenarios represent just the transport activities within the deployment process, the increment movement time could be represented as the sum of the individual times.

When technologies provided the capability to move more than one increment at a time, the movement time was divided equally over the number of increments moved. For example, a pallet train can contain six pallets, thus the time of the total move was divided by six.

Table 3. Estimated Times for Cargo Movement

Scenario	Transport Task	Task Time (Min)	Increment Movement Time Min)
1	Delay waiting for transport source	30	
	Forklift moves increment to CDF and then to the marshalling area	30	
	Forklift loads increment onto K-Loader in the marshalling area	15	
	K-Loader transports the increment to the aircraft	15	
	K-Loader is positioned against the aircraft	15	
	Increment is transferred into the aircraft	5	
	Pallet is locked into place	2	112
2	Delay waiting for transport source	30	
	Forklift moves increment to CDF and then to the marshalling area	30	
	Forklift moves increment from CDF to the aircraft	10	
	Forklift loads increment onto K-Loader	10	
	K-Loader transfer increment into the aircraft	5	
	Pallet is locked into place	2	87
3	Delay waiting for transport source	20	
	Tow vehicle pulls increment to CDF and marshalling area	15	
	Tow vehicle pulls increment to aircraft	10	
	Increment pushed or wenched into aircraft	15	
	Increment chained fast	15	75
4	Delay waiting for transport source	15	
	Increment moves to CDF and marshalling area	10	
	Increment moves to aircraft	3	
	Increment is driven or wenched into aircraft	10	
	Increment chained fast	15	53
5	Delay waiting for transport source	20	
	Dollie train pulled to CDF and marshalling area	5	
	Dollie trained pulled to aircraft	2	
	Pallets individually transferred to K-Loader	5	
	K-Loader transfers increment into aircraft	10	
	Pallet is locked into place	2	44
6	Delay waiting for transport source	20	
	Pallet train pulled to CDF and marshalling area	5	
	Pallet train pulled to aircraft	2	
	Pallet raised into aircraft with a ramping system and wheels raised	5	
	Pallet locked into place	2	34

3.1.2.4 MHE and Process Analysis

Table 4 presents the effectiveness analysis of the MHE currently used within six prevalent cargo movement system scenarios. This analysis helps establish the methodology for applying the metrics, provides a foundation for identifying and evaluating the strengths and weakness of existing technologies, and establishes a baseline for measuring the improvement potential of the technologies. Each scenario's MHE components are listed and their pertinence explained. Each component is also rated through the metrics described above.

The values assigned to the metrics are summed horizontally by scenario. Therefore the total value of the scenario improves as the summed numbers get smaller. For example, the metric entitled "Number of transfers among technologies and ground" measures the number of times that cargo is handled from the time of unit preparation to the loading of that cargo into the transporting aircraft. Each handling of the cargo requires the use of MHE, the availability of personnel to perform the handling, an increased performance time, an increased possibility of damaging the cargo, and an increased need to deploy additional support MHE and personnel to the receiving site. Indirectly, the more times the cargo is handled increases the use of the support MHE, thus increasing the maintenance and replacement costs.

Table 4. Rating of the Current Material Handling Systems

SCENARIO INFORMATION				METRICS												
				Speed of movement	Number of transfers among technologies and ground (a seamless movement)	Number of personnel required (Ease of cargo handling)	Deployment footprint of empty MHE	Operational footprint (operating space, turning radius, etc.)	Number of times MHE positioned against aircraft per load	Deployment footprint per increment	Efficient use of aircraft floor space (Ratio to current increment spacing - volume per sq ft)	Multiple use of MHE technology	Use of technology at both deploying and reception site	Technology operability with other services and commercial capabilities	Mean time between failures (Maintenance and reliability of MHE)	
Scenario 1 Palletized Increment with the K-Loader use for transport																
Phase			**Technology**													
Deployment			Scenario		7					3						
			Pallet				0.2	1				2	1	1	1	
			Forklift			2		1				1	1	1	2	
			K-Loader			4		3	4			2	1	1	3	
				112	7	6	0.2	5	4	3	0	5	3	3	6	42.2
																112
Scenario 2 Palletized Increment with forklift used for transport																
Deployment			Scenario		7					3						
			Pallet				0.2	1				2	1	1	1	
			Forklift	0		2		1				1	1	1	2	
			K-Loader	0		3		3	1			2	1	1	3	
				87	7	5	0.2	5	1	3	0	5	3	3	6	38.2
																87
Scenario 3 Rolling Stock (Non-Powered)																
Deployment			Scenario		1					2						
			Rolling Stock				1	2				2	1	1		
			Truck/tractor			2		2	13			1	1	1	2	
				75	1	2	1	4	13	2	0	3	2	2	2	32
																75
Scenario 4 Rolling Stock (Powered)																
Deployment			Scenario		1					1						
			Rolling Stock		0	3	1	2	13			2	1	1	2	
				53	1	3	1	2	13	1	0	2	1	1	2	27
																53
Scenario 5 Pallet dollies used to transport pallets																
Deployment			Scenario		2					4						
			Pallet dolly				0.2	1				1	1	1	1	
			Truck/tractor			2		2				1	1	1	2	
			Forklift			2		1				1	1	1	2	
			K-Loader			3		3	1			4	1	1	3	
				44	2	7	0.2	7	1	4	0	7	4	4	8	44.2
																44
Scenario 6 Wheeled pallet to transfer cargo																
Deployment			Scenario		1					2						
			Pallet dolly				0.2	1				1	1	1	1	
			Truck/tractor			2		2				1	1	1	2	
			Ramp			4		0	1			2	1	1	3	
				34	1	6	0.2	3	1	2	0	4	3	3	6	29.2
																34

The estimated process timing ranges from a current 112 minutes to approximately 60 minutes with process and technology changes. The two primary factors impacting the timing are the availability of support MHE to move the cargo and the characteristics of that cargo which requires support MHE for its movement. Cargo ready for movement but needing support MHE must wait for that MHE to be available. For pallets, this delay currently averages 30 minutes. For rolling stock, including the proposed wheeled pallets capable of being pulled by unit owned vehicles, the way time could be reduced to approximately 15 to 20 minutes.

Additional time savings relate to the use of wheeled cargo during ground movement, and especially if multiple increments can be moved simultaneously by one tow vehicle. The third major time savings occurs when the wheeled cargo can transition into the pallet structure, allowing the use of the aircraft pallet locking system rather than using the chain down approach.

The metrics, other than timing, indicates less effective resource movement in scenarios 1, 2, 4, and 5. The common aspect among these scenarios is the use of the K-Loader, which impacts the processing time and significantly increases the deployment footprint. The optimal MHE concept involves the use of wheeled pallets with a ramping system or loading system that eliminates the need for K-Loader support.

3.2 MHE Research Opportunities

The previous discussion provides insights into the grouping of characteristics necessary to improve the cargo movement process. A few of the concepts identified during the course of this program are described below.

3.2.1 Wheeled Pallets

Pallets with retractable wheels allow for the transition between efficient ground movement and aircraft loading. Raising and lowering the wheels could be done manually or through pneumatics.

3.2.2 Improved Containers

Containers made of lighter materials, with capability to fold down to facility movement when transporting empty, and with the retractable wheel capability as described for the wheeled pallets. Using container capabilities being developed for commercial airlines to protect against explosions, similar safety measures would reduce the restrictions due to hazardous material packing.

3.2.3 Tow Capabilities

Having wheeled pallets and containers allows for the towing of those MHE individually or in trains. Train towing can be accomplished by vehicles not uniquely designed for that purpose, thus providing multipurpose capability. Movement of individual pallets and bins could be accomplished with small tow motor units that plug into an axle.

3.2.4 Multiple Use of MHE

Research into the design of MHE should identify multiple use capabilities for MHE. For example, wheeled pallets and bins, with modules attached, provide the potential for transporting personnel on the ground and within the aircraft. On the ground, the pallets and bins could become towable buses, or with the attachment of a small drive unit could become a self-powered bus. On the ground, the pallets and bins could become patient moving devices operating in conjunction with the hospital and patient litters being developed by Northrop-Grumman. In the air, the pallets and bins could be transformed into patient carrying units facilitating the loading and unloading of patients.

3.2.5 Portable Rail System

Some Soviet transport aircraft contain a rail system built into the top of the cargo hold. This rail system allows for loading and unloading increments directly from the ground with no other MHE support capability. While probably not practical to suggest the redesign of current aircraft to incorporate this rail system, a more effective way would be to develop a mobile rail system that links into existing aircraft. This system could possibly support the loading and unloading at both the side and end.

For simplicity, the rail system could be built on a wheeled frame, either powered or non-powered, with the rail capability of extending in both height and length. The far end of the rail would connect to a support structure inside the aircraft. Using a pulley system, increments could be lowered or raised into the aircraft with minimal effort.

3.2.6 Improved Support for Combat Unload

As the Air Force is assigned missions at more locations throughout the world along with shortened response times, the need to increase unload speed will become an important consideration. Specifically, the use of combat unloads in which cargo is quickly removed from the aircraft reduces aircraft ground time at the reception site. Unloading this quickly requires the capability to move the increment off the runway so as not to hinder subsequent planes landing, but without the need for increased MHE.

Mobility and reduced need for support MHE equates to having wheeled increments. For the combat unload, applying the concept of retractable wheels on pallets and containers creates a potential problem because the wheels could not be dropped during the combat unload, leaving the increment on the runway and difficult to move. Two possible approaches could be used to address the problem. One, a forklift could lift each increment to allow the wheels to be dropped and then move to subsequent increments as a tow vehicle forms an increment train. Two, lowering the wheels could be accomplished using air pressure much like how racecars are raised during a pit stop. A tow vehicle with an air supply could raise each pallet as the increment train is formed.

3.2.7 Aerial Drops

Aerial drops provide the potential for increasing the operational usage, in terms of both safety and productivity: safety in terms of being less vulnerable to attack and in reducing the higher operational safety risks of landing and taking off; productivity in terms of minimizing the time the aircraft is stopped for loading and unloading. The challenge to the technology development focuses on the following areas:

- Safe and effective extraction of cargo from the aircraft
- Accurate placement of the cargo in the targeted area
- Quick retrieval of the cargo from the targeted area

3.3 Transport Vehicle Research

While not emphasizing technology improvements to the transport aircraft as part of this program, a couple of issues related to the transport aircraft identified during data collection impact other technologies aspects.

The major improvement taking place with respect to transport aircraft technology is the purchase of the C-17 and the anticipated changes to the mix of all transport aircraft. Two other aircraft technology changes being discussed are the load-by-wire and articulated loading ramp systems, both of which are envisioned for design into the aircraft structure. With these technologies, cargo, primarily containerized cargo could be moved from the ground directly into the aircraft, reducing the need for K-Loaders.

While no technology improvement concepts were specifically identified during the data collection for the aircraft, the most significant problem identified within the aircraft was the increment locking approaches. The pallet locking system provides a very effective and efficient approach because it is simple, fast, and facilitates the various types of unloading. The non-palletized locking system uses chains to fasten the increments and is slow, laborious, and requires training. More importantly, the chaining technique hinders the fast unload of cargo at the reception site. Therefore, if research were to be directed at the aircraft, two areas would be the design of non-palletized cargo that could use the pallet locking system and the design of an aircraft locking system that improves the chain-down approach.

3.4 Information Handling and Planning

The information research efforts focus on capabilities to quickly access and process large quantities of information with the goal of improving resource movement flow control through optimized use of all resources to include personnel, cargo, MHE, and transport aircraft. The following subparagraphs discuss the potential research requirements of the four information functions of information collection, resource movement scheduling, decision support research, and command and control research.

3.4.1 Information Collection Research

The past few years produced significant research, design, and development for technologies related to information collection within both commercial and military operations. The use of information tags linked to satellite communications by companies such as Federal Express allows for the tracking of packages throughout the world. Therefore, rather than the military directing resources at involvement in resource tagging research, the military should capitalize on the commercial research and developing efforts by selecting and implementing those technologies at the appropriate times. What is important from an information collection perspective is the effective separation and location related to resource tracking. A major goal of the tag development is the increasing amount of information capable of being stored on the tag. For various reasons, however, not all information should be stored on the tag, nor should all information be stored in a centralized database or a set of databases.

The optimal mix of information storage lies somewhere between those two extremes, the definition of which becomes the research focus for information collection. Determining the mix of information storage is driven by the information requirements for the resource movement process to address factors such as access speed and security, functional application, and information users.

3.4.2 Scheduling Research

The transportation scheduling research focuses on the effective use of resources, primarily the transport aircraft and MHE, as they are becoming some of the most valued assets during a deployment. The information sources will be the resource tracking capabilities and those specifying when resources must be positioned at the reception site. Using modeling, simulation, and expert system technologies, the scheduling system would first identify the resource transport requirements, and the availability and current location of transport equipment. Then the scheduling system would compute the best mix of transporting capabilities to optimize the effectiveness as well as the cost of the move.

3.4.3 Decision Support Research

The decision support research provides an interactive capability for improving the operational effectiveness of decision-makers. The research would evaluate the resource movement process to identify critical decision-makers and define their decision-making requirements. The research would identify the interactions among those decision-makers and establish a top-level view of the decision-making process supporting the resource movement process. From the decision-making process definition can be developed an decision support system.

3.4.4 Command and Control

The command and control research focuses on the development of decision support technologies that allow the individuals to concentrate on decision-making rather than information organizations. The technology will receive status information about the resource movement status, compare it against the scheduled activity, identify the variations, and present the variations and suggested corrective actions to the command and control personnel. Once presented, the command and control system supports changes to the suggested actions and distributes those actions.

3.5 Process Research

Process research opportunities have been identified for process analysis, continued process improvement, and in-flight briefings.

3.5.1 Process Analysis Research

The resource movement process and the associated information form the foundation for establishing the technologies requirements and specifications needed to effectively implement the process. Therefore, the first step in the research analysis requires an analysis and streamlining of the movement process. Through this analysis, each step in the process will be evaluated with respect to its value, with the process adjusted to remove those identified as non-value-added. In parallel with the process streamlining, the information associated with the process steps will be streamlined or optimized to retain only that which is needed and to define the relationships among the needed data elements.

The LOG-AID program addressed the streamlining of resource movement at the deploying site. Continuing the same analysis first into the reception site and then the aerial port will complete the streamlining effort. The reception site analysis is suggested for completion first since it establishes many of the operational requirements that impact both the deploying and aerial port operations.

The process and information analysis would then extend to the aerial port operations. During data collection, aerial port operations were identified to be probably the greatest bottleneck in the resource movement process. An analysis of aerial port operations will identify the accuracy of the supposition along with the cause of the problem if the supposition is true. This research will help evaluate alternative concepts such as the use of Regional Control Centers (RCCs) to centralize the source of grouped capabilities. Using the grouped capabilities situated at approximately eight strategically placed locations throughout the world, along with increased transport capabilities provided by the C-17, may allow for the future elimination or reduced reliance on aerial port operations. This would eliminate a major, time-consuming event in the resource movement process.

3.5.2 Continued Process Improvement

This research aims at developing the expert system and decision support capabilities necessary to evaluate the effectiveness of a process and identify processing problem areas. This analysis would occur as both background and real-time efforts. As a background effort, continuing problem areas would be identified and presented to a process improvement team along with suggested flow changes. As a real-time effort, the technology would identify variations between scheduled and actual status to initiate changes to the process and ensure the successful meeting of the schedule.

An extension of this technology would be its use as a total process training capability for the movement of resources. Through its access to actual deployment data, the training would be updated as changes are made to the process. It would also allow for the changing of scenario conditions to evaluate various operational conditions.

3.5.3 In-Flight Presentation Research

As part of the deployment process, personnel receive a briefing with information about the destination, to include the political environment, cultural and custom issues, weather, and general operating conditions such as altitude and terrain. To meet the timelines of the Air Force's future operational goals, the continued use of the Personnel Deployment Function (PDF) may be reduced or eliminated. This change requires the presentation of the briefing in another manner.

This briefing could be presented during the flight to the destination. As part of this in-flight briefing, additional information such as pictures and videos of the destination could be included to get personnel acquainted with the physical setup of the reception site prior to their arrival.

The briefing could be presented using a disk-type plug-in module received as the individual enters the aircraft for departure. Satellite communication links could be used to transmit additional information using cyclic broadcasts throughout the trip.

4 Research Agenda

The literature review, data collection interviews, and resource movement process analysis identified the four general areas of transport aircraft, resource handling, information handling, and process analysis as having opportunities for improvement through research. Within the scope of this program, research directed at the transport aircraft is not being addressed. Prioritization of research opportunities in the remaining three areas ensures the most benefits provided to the user while minimizing the resources expended.

Two major factors guiding the prioritization are the level of importance placed on the needs and deficiencies by the users, and the interactions existing among the three areas. For the user perspective, the most critical area is resource handling, followed by information handling. From an analysis perspective, the most critical area is the process definition, which defines the functional requirements and performance specifications for the technologies selected to implement the process. Therefore, while there can be parallel research among the three areas, the process definition research is recommended first, followed by resource handling and information handling.

4.1 Process Research Agenda

The process research agenda focuses on a combination of streamlining the current resource movement process and a vision for what movement requirements will look like in the future. For the near term, major changes to the movement concept will probably not occur. Therefore, directing process research toward formally documenting and analyzing the process will identify and remove non-value added steps within the process and will optimize the effectiveness of the remaining steps. In the long term, significant changes in aircraft capabilities and deployment needs may enhance the potential for eliminating or modifying the aerial ports as they currently exist.

- In support of these process improvements, research can be directed toward establishing the methodology for documenting and analyzing the effectiveness of a process. This would include the capability to test various process implementation scenarios.

- Development of an in-flight briefing and information presentation technology to enhance the knowledge of deploying personnel about their destination.

4.2 Resource Handling Research Agenda

Developing this agenda begins by looking at near-term problems likely to remain into the distant future. Specifically, this relates to the increased cargo movement speed on the ground, its loading into the aircraft, and its unloading and distribution at the enroute and reception sites. This research begins with the development of integrated MHE having the following characteristics.

- Both wheeled and non-wheeled capabilities with easy transition between the two characteristics while moving into or out of the aircraft, or after it has already been placed on the ground.

- Modules to include personnel movers, patient movers that interface with the patient support technologies being developed by Northrop-Grumman, and a trailer design for carrying all types of cargo.

- A self-propelled mode of operation made possible by the attachment of a small drive. The self-propelled capability may support the pallet movement using remote control to minimize the need for support MHE as tow vehicles.

- New materials that are attachable to the bottom of the pallet to allow its sliding on hard surfaces as a secondary method of movement if the wheel cannot be lowered for some reason.

Development of improved containers having the following characteristics:

- Lighter, cheaper materials that are easier to manufacture, collapsible when empty, and improved strength to protect against dangerous events such as internal explosions during flight.
- Retractable wheels as those described for new pallets.
- Insertable modules providing for a variety of secondary uses.

Requiring probably the greatest research effort but providing the greatest return is the development of replacement technologies for the current K-Loaders. Two major requirements for the replacement technology are deployability and dependability. Potential technologies include the following:

- Use of commercial style, deployable, two-platform loaders capable of transferring increment to and from ground level.
- Ramping system for loading and unloading. For unloading, the ramp uses roller coaster technologies to allow an increment to be pushed from the aircraft with its fall slowed as it reaches the ground.
- Mobile rail system that ties into the aircraft allow for the hoisting of increments into and out of the aircraft.

4.3 Information Handling Agenda

The suggested research agenda for information handling technologies builds around the areas of status collection and tracking, scheduling, decision support, and command and control. The suggested research agenda includes the following:

- Using the streamlined process definition, identify the requirements for information collection and tracking, including information needed in analyzing the operational effectiveness of the resource movement process.

- From an information usage perspective, determine how the information should be organized to best utilize the tagging technologies. Of specific importance in this area is ensuring compatibility with commercial tracking capabilities.

- Develop an expert system capable of accessing status information for cargo and cargo movement resources, and aggregating that information with user requirements to generate a suggested cargo movement schedule. This technology will interface with the TRANSCOM scheduling of their aircraft.

- Develop a decision support system that interfaces with decision-makers, allowing them to review and adjust as necessary the suggest schedule. This development will build upon the process analysis and process improvement effort to identify decision requirements and their hierarchy such that the appropriate information can be effectively presented and formatted.

- Develop a command and control technology that systematically compares the actual status to the planned schedule and to suggest when and what corrective actions should be taken.

- Develop a passive process improvement technology that builds upon the command and control technology by capturing when variations to the schedule occur and collecting the information necessary to evaluate the cause of the variation. From this information trend analysis will be generated, resulting in the identification of areas for improvement.

4.4 Notional Research Schedule

Figure 7 presents a notional research schedule. The focus of this schedule is the starting sequence of the research, with estimated relative durations for the major tasks.

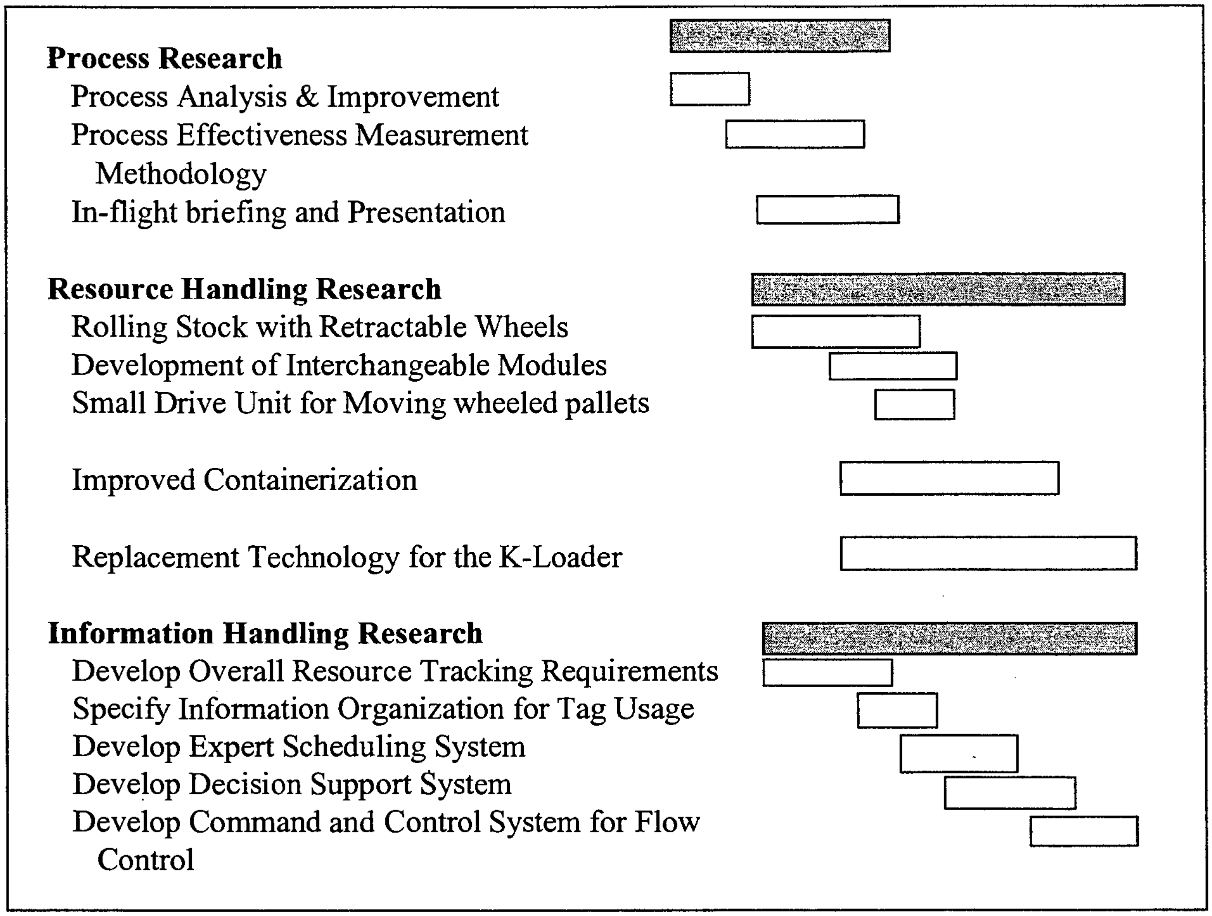

Figure 7. Notional Implementation Schedule