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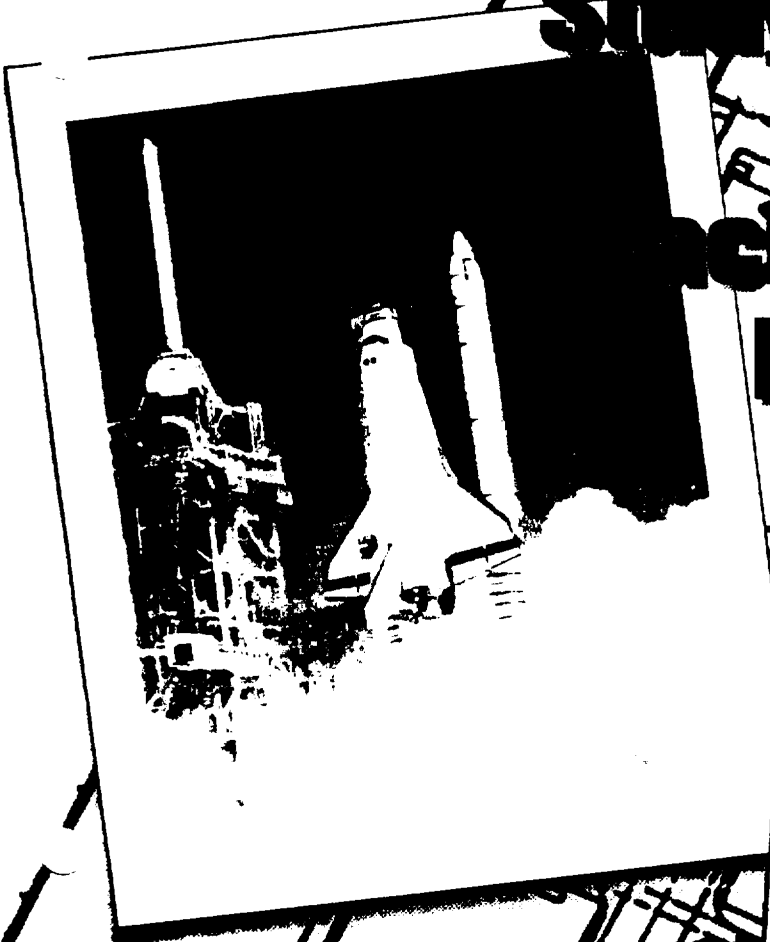
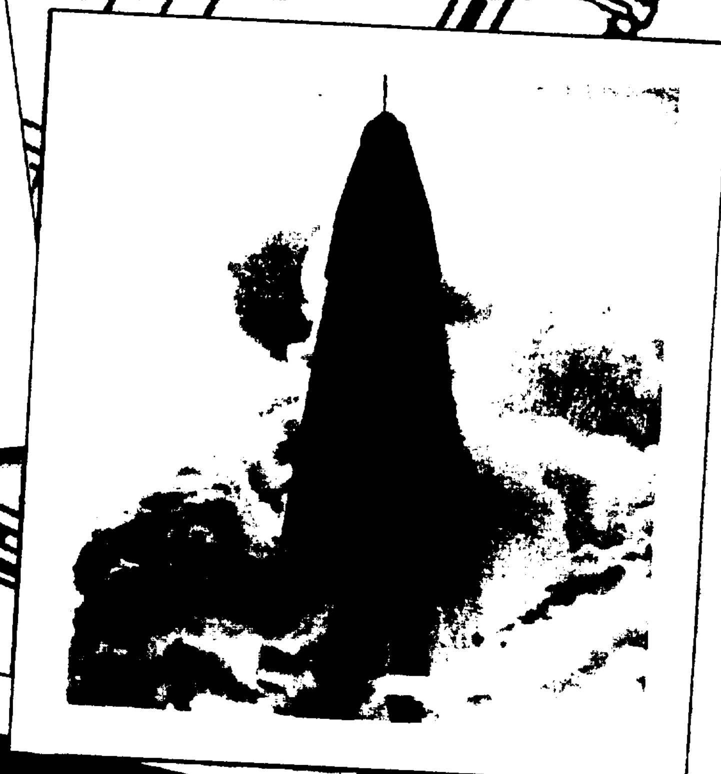
Study of Launch Site Processing and Facilities for Future Launch Vehicles





Final Report

March 1995

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Launch Site Processing and Facilities
for
Future Launch Vehicles
Contract NAS10-11999

Final Report

March 1995

Developed for

The National Aeronautics and Space Administration
Kennedy Space Center
Director, Facilities Engineering and Project Management

McDonnell Douglas Space and Defense Systems
Kennedy Space Center Division

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Abbreviations and Acronyms

4GLs	Fourth generation language for database development
ACC	Advanced Carbon Carbon
ALAP	As-Late-As-Possible
APU	Auxiliary Power Unit
ASAP	As-Soon-As-Possible
CAD	Computer-Aided Drafting/Drawing
CALS	Computer-Aided Acquisition and Logistics
CALS	Computer Aided Logistics
CASE	Computer-Aided Software Engineering
CBT	Computer-Based Training
CBT	Computer Based Training
CG	Center of Gravity
CLV-P	Cargo Launch Vehicle - Piloted
DC-X	Delta Clipper-Experimental
DoD	Department of Defense
DOS	Disk Operating System
DR	Discrepancy Report
DXF	Special file format for Autocad drawings
ECLSS	Environmental Control and Life Support System
ET	External Tank
FRSI	Flexible Reusable Surface Insulation
FSS	Fixed Service Structure
GOST	Ground Operations Simulation Technique
GSE	Ground Support Equipment
GUI	Graphical User Interface
HRSI	High-Density Reusable Surface Insulation
IGES	Initial Graphic Exchange Specification
IGES	International Graphic Exchange Specification
IPR	Interim Problem Report
IR	Infrared
klb	thousands of pounds
KRS	Knowledge Representation System
KSC	John F. Kennedy Space Center, NASA
LaRC	Langley Research Center
LES	Launch Escape System
LH2	Liquid Hydrogen
LOX	Liquid Oxygen
LVNRA	Study of Launch Site Processing and Facilities for Future Launch Vehicles
MERA	Multiflow Expert Resource Assessment
MIT	Massachusetts Institute of Technology
MLP	Mobile Launch Platform
MMU	Model Management Utility
MPX	Microsoft Project Export

Abbreviations and Acronyms - continued

MSFC	George C. Marshall Space Center
NASA	National Aeronautics and Space Administration
NRA	National Research Announcement
ODA	Operations Definition Assistant
OIA	Operations Impact Assessor
OMS	Orbiter Maneuvering System
OPF	Orbiter Processing Facility
P/A	Propulsion/Avionics (recoverable module)
PC	Personal Computer
PC	Personal Computer
PLS	Personnel Launch System
PR	Problem Report
RDB	Relational Data Base
RF	Radio Frequency
RLV	Reusable Launch Vehicle
RSRM	Reusable Solid Rocket Motor
RSS	Rotating Service Structure, or Relational Storage System
SOW	Statement of Work
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SSME	Space Shuttle Main Engine
SSTO	Single-Stage-to-Orbit
STS	Space Transportation System
TCMS	Test and Checkout Management System
TCMS	Test, Checkout and Monitoring System
TPS	Test Preparation Sheet
TPS	Thermal Protection System
VAB	Vehicle Assembly Building
VDA	Vehicle Definition Assistant
VR	Virtual Reality
VR	Virtual Reality
WCTRV	Winged Cargo Transport and Return Vehicle
WYSIWYG	what-you-see-is-what-you-get

1.0 EXECUTIVE SUMMARY

Kennedy Space Center (KSC) is the primary space transportation system launch site for the National Aeronautics and Space Administration (NASA), and over the last 35 years, its personnel have accumulated a wealth of experience and expertise in both manned and unmanned launch vehicle operations. NASA has utilized this expertise by having its KSC personnel assess the impact that the processing of proposed future vehicles would have on the launch site in terms of such things as resource requirements, processing timelines, and facility impacts. However, the assessment process is far from perfect - quick turn-arounds are often requested and the process is relatively slow, often estimates are based on "gut feel," are often challenged and hard to defend, and adjustments are often made based on undocumented agreements and assumptions that are subsequently hard to recall. Further, KSC is faced with deterioration of its experience base, as many of its more experienced personnel retire.

1.1 Objectives

As a result of the aforementioned shortcomings, KSC issued a request for proposals to conduct research, which would provide innovative and creative approaches to assess the launch site impact for a range of manned and unmanned space transportation systems. The research was to be defined in four general areas, as follows:

- Development of innovative approaches and computer-aided tools
- Operations analysis of launch vehicle concepts and designs
- Assessment of ground operations impacts
- Development of methodologies to identify promising technologies

1.2 Schedule

Proposals were submitted in response to a competitive procurement on 1 October 1992, and McDonnell Douglas Aerospace Space Systems, Kennedy Space Center was announced as the winner in December of that year. Negotiations were completed and the 18-month contract was awarded on 21 April 1993. On 20 October 1994, the period of performance was extended to 31 March 1995.

1.3 Approach

Our approach was to automate our proven manual assessment methodology in a computer-aided tool that would be a user-friendly, object-oriented, artificial intelligence application. This application would feature model-based reasoning and discrete event simulation. During the development of this tool, the Operations Impact Assessor (OIA), we performed analyses of launch vehicle concepts and designs and assessments of ground operations impacts using our manual assessment methodology. As use of the manual processes identified technologies that had potential for improving launch site operations, they were assessed to determine how they could be utilized, and what the likely impact would be. In addition, we provided a design concept for performing this technology assessment using the OIA.

1.4 Products

The primary research product was the OIA software application and its related documentation; however, there were a number of other significant products that resulted from the research, as follows:

- *Launch Site Operations Design Data Book*, which provides design recommendations to improve launch vehicle operability, and related enhancements to launch site operations.
- *Operations Impacts Assessment Reports*, which documents, for a number of launch vehicle concepts, ground processing scenarios and timelines, resource drivers, and operational sensitivities.
- *KSC Launch Vehicle Processing Facility Data Base*, which provides ready access to facility characteristics that are important to launch site operations. It is not called for by the contract, but was developed to populate the OIA. It can be used in a stand-alone mode, and it also has a search capability to identify those facilities having certain requested characteristics
- *Critical Technologies and OIA Implementation Methodology*, which identifies those technologies with the greatest potential for improving launch site operations. It also documents a design concept for performing a technology assessment using the OIA.

1.5 Summary of Conclusions and Recommendations

This research has shown that many problems encountered when using manual techniques for assessing the launch site impact of future space transportation systems, can be overcome through the use of the automated OIA application. Further, the assessments can generally be completed more quickly, and the results are solidly based on past experience with established processes, and on conscious and fully documented deviations from those processes. As such they are readily defendable. The impact of alternative processing options can also be easily assessed.

As the OIA application is used, it is certain that users will identify features that they would prefer to have performed in a different manner. Also, there are additional features, such as automatic conflict resolution, that they would like to have added to the application. It is recommended that funding be provided to improve and extend the OIA capabilities.

Many future launch vehicle design features have been identified in the *Launch Site Operations Design Data Book*, that if implemented by vehicle designers, would significantly improve the efficiency and cost-effectiveness of launch site processing. It is recommended that failure to incorporate these features into future space transportation system designs be permitted only after careful consideration at the highest program levels.

The processing timelines developed for conceptual launch vehicles were based on designs provided by the several design agencies. These designs were generally evolutions of existing vehicles or used components derived from existing components (e.g., SSMEs). Stated differences from current designs formed the basis for reductions in launch site processing requirements. The resulting processing timelines were often criticized for being too long; however, the design agencies provided no rationale for their further reduction. Recommendations contained within the *Launch Site Operations Design Data Book,* if followed by the design agencies, would have provided the basis for further reductions.

2.0 INTRODUCTION AND TECHNICAL APPROACH

This report documents the results of the Study of Launch Site Processing and Facilities for Future Launch Vehicles, performed in response to a National Research Announcement, the first ever issued by the National Aeronautics and Space Administration-Kennedy Space Center (NASA-KSC). Its purpose was to provide creative and innovative approaches to assess the impact to KSC and other launch sites for a range of candidate manned and unmanned space transportation systems. Its activities, analyses, and evaluations were contained within the four tasks, shown in Figure 2-1: Development of Innovative Approaches and Computer-Aided Tools, Operations Analyses of Launch Vehicle Concepts and Designs, Assessment of Ground Operations Impacts, and Development of Methodologies to Identify Promising Technologies.

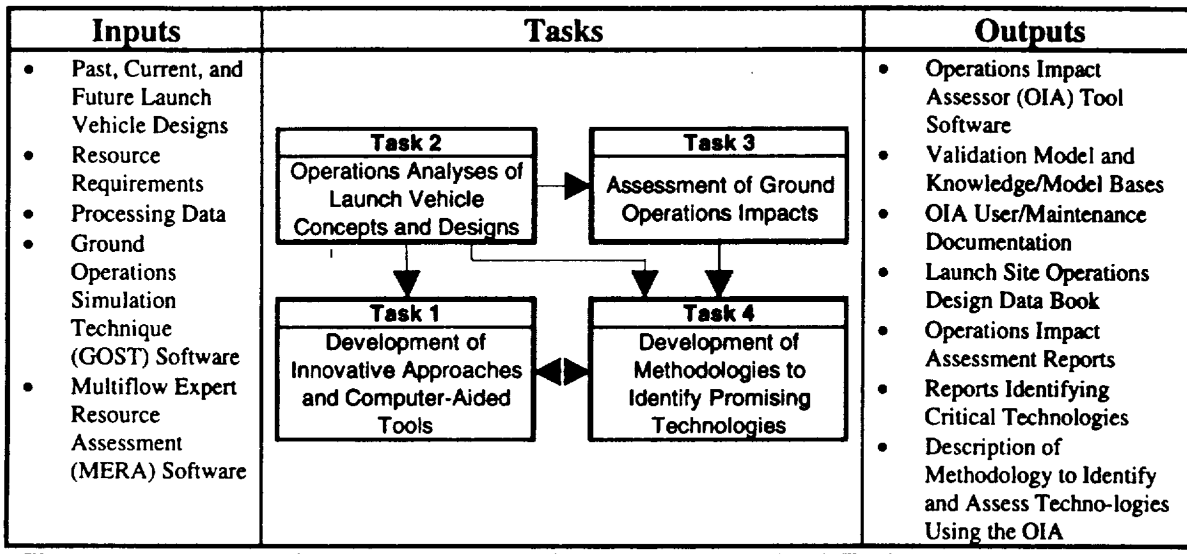

Figure 2-1 The Technical Approach Is Defined By The Four NRA Tasks.

This section briefly describes the technical approach used to accomplish the four study tasks. Each task is discussed in greater detail in subsequent sections.

Task 1, *Development of Innovative Approaches and Computer-Aided Tools*, developed the OIA application software, which will enable the user to accomplish automatically that which was accomplished manually in Tasks 2 and 3. The proven manual techniques utilized in Tasks 2 and 3 provided the basic methodology for Task 1. Our approach was to build upon our existing object-oriented modeling environment and simulation technology. We incorporated a frame system, developed under IRAD, that was capable of simultaneously managing multiple software models. Intelligent assistants were developed to help the user construct a model of the conceptual launch vehicle, and then to define its launch site processing operations. An extensive template library of existing launch vehicles and their processing operations was included to permit rapid construction of a launch vehicle and definition of its operations using components, or modifications of components, from these existing vehicles. An analysis engine was developed to simulate the launch site processing, and reporting utilities were developed to display the processing results.

The resulting OIA application is generic in its capabilities, and is capable of modeling any generic object and analyzing its performance through any process. The software was developed using a utility that will permit it to be easily ported to operate on a number of computer platforms, and its architecture will permit easy extension of its capabilities to meet new requirements.

In Task 2, *Operations Analyses of Launch Vehicle Concepts and Designs*, data from both manned and unmanned launch vehicles and their associated ground support equipment (GSE) were collected and analyzed. For consistency of nomencalture, these vehicles were divided into elements, and these elements were further decomposed into common systems and subsystems. The data were analyzed to identify launch operations drivers for each subsystem. These data formed the basis for design recommendations in the *Launch Site Operations Design Data Book.*

Conceptual launch vehicles subsystems were examined to see whether any launch operations drivers had been included in the design. When found, these drivers formed the basis for recommending design changes.

In Task 3, *Assessment of Ground Operations Impacts*, conceptual launch vehicles were viewed as evolutions of current launch vehicles. Evolutionary changes in launch vehicle design, defined by the design agency, such as the availability of built-in-test capability, provided justification for decreases in launch site processing requirements and timelines. Processing facilities were assessed based on vehicle physical properties and processing requirements versus existing facility characteristics and capabilities, such as door dimensions, crane capacity, and suitability for hazardous processing. Appropriate facilities were identified when requirements could be satisfied, and facility modifications or new facilities were identified if suitable facilities did not exist. Pictorial scenarios were then constructed, and processing timelines were developed.

As an adjunct to this task, a facilities data base was constructed (using the Claris FileMaker Pro application) to document and provide ready access to facilities data gathered from several sources. It provides ready access to facility characteristics that are important to launch site operations. It also has a search capability to identify those facilities having certain requested characteristics. These facility data were also loaded into the OIA.

In Task 4, *Development of Methodologies to Identify Promising Technologies*, technologies identified in Tasks 2 and 3 were examined with respect to several generic processing tasks. They were then grouped under the tasks that would most likely provide benefit from their utilization. A list of potential commercial spin-offs from technologies was also developed. Finally, a conceptual design was developed for adding to the OIA the capability to identify vehicle designs and launch site processes that could benefit most from the introduction of technology. This conceptual design, if implemented, will identify when the technologies are needed and what their expected impacts are likely tc be, based upon the anticipated technology maturity level.

3.0 TASK 1 - DEVELOPMENT OF INNOVATIVE APPROACHES AND COMPUTER-AIDED TOOLS

3.1 Task Overview

The *Statement of Work for Launch Site Processing and Facilities for Future Launch Vehicles* states, "The contractor will develop innovative approaches and computer aided tools for evaluating launch site space vehicles ground processing impacts including operability, facilities, GSE, processing requirements, timelines, and resources for future launch vehicles including payload integration in a quick response assessment environment."

In keeping with the Statement of Work, we proposed to accomplish the above goal through the SOW's five suggested subtasks. Each task is briefly described below.

3.1.1 Define and Refine the Architecture

The government requested that the requirements and system concepts for the Operations Impact Assessor (OIA) be coordinated prior to initiation of software development. On July 13, 1993 we presented a document to the customer for their review in fulfillment of this requirement. In addition to this formal requirement, we initiated weekly (when necessary) and monthly customer meetings as development progressed, to ensure it proceeded in accordance with the customer's requirements.

3.1.2 Develop Intelligent Assistants

Two intelligent assistants were to be developed. One to configure a launch vehicle from its constituent components, and the other to define the vehicle's launch site processing functions. These intelligent assistants were to help the user generate a new vehicle concept quickly through the program's menus.

3.1.3 Develop Utilities

A key component of the Task 1 effort required the development of three utilities, Model Management, Analysis, and Reporting utilities. The Model Management utility was to provide a link to existing models and other internal data sources by managing the storage and retrieval of models, and allowing for import and export to other software programs.

3.1.4 Develop Knowledge Bases

The government also requested the development of two knowledge bases. The first, a Vehicle Definition Knowledge Base, was to contain useful components that could be used as a guide in the development of other launch vehicles. The second, an Operations Definition Knowledge Base, was to be used as a guide for developing the processing logic for new launch vehicles.

3.1.5 Validation of the OIA

Finally, validation of the Operations Impact Assessor was to be accomplished by unit testing each module of the software, and then performing an integrated test of the software by modeling a reasonably complex vehicle as specified by the government.

3.2 Architecture

As mentioned earlier, we completed the specification and documentation of the OIA's system concepts and requirements in the summer of 1993. This section will update the description of the software architecture to its current state, since it has evolved somewhat since the first specification. The current architecture is displayed in Figure 3-1 below.

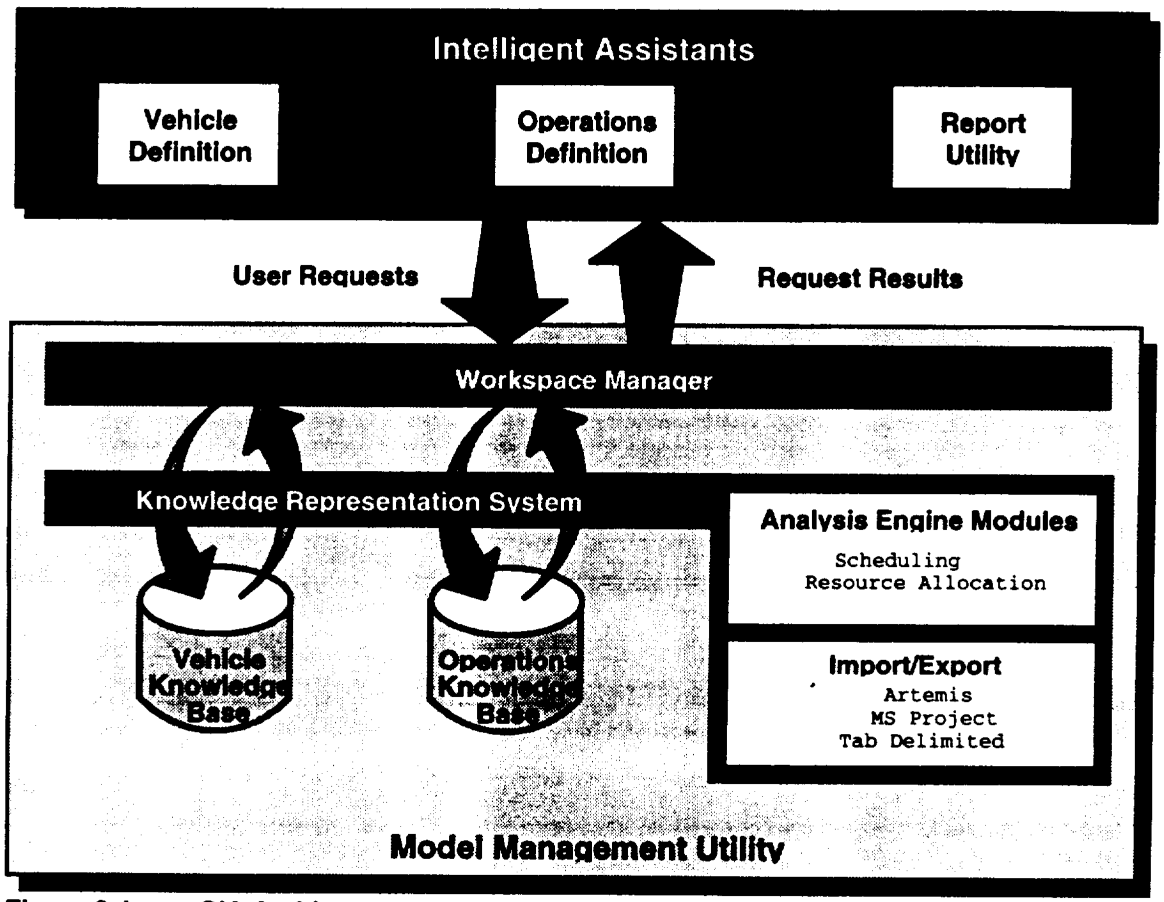

Figure 3-1: OIA Architecture

3.2.1 Model Management Utility

This subsection describes the lowest layer of the OIA architecture, the Model Management Utility (MMU). The intelligent assistants, together with the MMU, assist the user in developing *vehicle process models* from information stored in the *template library* and user *project files*. This information is displayed in a *workspace*. Model information is managed by controlling the functions of creating, modifying, deleting, and querying information in a workspace, and storing and retrieving information to and from disk. The template library is a special, "read-only" project file that contains approved information available to all users. All other project files can modified as long as the user working in the OIA has been given the appropriate permissions by the operating system.

The MMU modules are the *workspace manager* and the *knowledge representation system*. These modules provide the functions for creating a project file, reading the template library into the workspace, working within and querying the workspace, storing the workspace in a project file on disk, and reading a project file from disk into the workspace. All information is stored in an *object-oriented representation*.

3.2.1.1 Object-Oriented Representation

The template library, workspace, and project files employ an object-oriented schema to represent vehicle and process models. The models contain *objects* representing launch vehicles, payloads, equipment, facilities, and their components. Objects are described in terms of their *attributes*, *behaviors*, and *relationships* to each other. Attributes describe an object in quantitative terms such as mass, thrust, or dimensions, or in qualitative terms such as an ability to satisfy NASA objectives. Behaviors describe a scenario of activities that require some number of resources over an interval of time. Relationships simply name an association between two objects. For example, a vehicle is *processed-in* a facility and *carries* payloads. This aspect is hidden from the user and is part of the artificial intelligence supplied by our innovative design.

3.2.1.2 Object Hierarchies

The OIA makes primary use of two types of hierarchies: *categories* (the kinds of objects in the model) and *components* (the parts of a particular object). In the popular Rumbaugh object-oriented design notation, these terms are known as *generalization* and *aggregation*, respectively. However we will use the more "layman" terms of categories and components. Categories can be broken down into subcategories as needed, and component hierarchies can break down vehicles, facilities, and GSE into their constituent parts, all the way down to the "nut-and-bolt" level as in a traditional bill-of-materials inventory system.

3.2.1.3 Workspace

The workspace provides the user with an area to develop models without modifying either the template library or others' work. The user, via the intelligent assistants and the workspace manager, will utilize his own private workspace. The user will develop a model by modifying library templates that he has read into his workspace. OIA utilities will query the workspace for their information as well. Figure 3-2 below, shows a vehicle definition workspace with its categories hierarchy on the left and the components hierarchy on the right.

3.2.1.4 Workspace Manager

The workspace manager handles all user-initiated interaction form within a workspace. Its function is to control access to information in the workspace from the reporting utilities and the intelligent assistants. In this role, the workspace manager acts like a server to all of the model management clients, thereby separating model storage and retrieval functions from information presentation and collection.

3.2.1.5 Knowledge Representation System

The knowledge representation system is the lowest layer in the system and is the last stop in all data query and manipulation requests. It is very similar in function to the relation storage system (RSS) in traditional relational databases (RDB's). Instead of employing a two-dimensional table, as in RDB systems, we use a *frame* data structure to represent information.

Frame data structures were invented in the late 1970's at MIT to overcome the shortcomings of the semantically impoverished relational data model. The data structure has matured considerably over the past 15 years, but few implementations have endowed it with the full database capabilities of multiple exclusion, crash recovery, logging, etc. Furthermore, we are not aware of anyone who has provided these capabilities in frame system implemented in the C++ programming language.

3.2.2 Intelligent Assistants

The OIA provides two *intelligent definition assistants* to aid the user in constructing a vehicle process model: a *vehicle definition assistant* and an *operations definition assistant*. These definition assistants provide window-based user interfaces, supported by *knowledge bases* and *definition utilities*, to guide the user in browsing and selecting objects from the template library and in modifying those objects to create a launch vehicle and its process flow. The knowledge bases supply information describing how existing vehicles and process flows are configured and defined. The definition utilities support several import and export formats for creating and sharing models.

All of the intelligent assistants will interface solely with the model management utility to access model information. Figure 3-1 illustrates the intelligent assistants and their interfaces.

3.2.2.1 Vehicle Definition Assistant (VDA)

The OIA provides a vehicle definition assistant to help the user define a vehicle. The user can create a vehicle definition by reading template library objects into his workspace. He can modify the attributes and composition of an object in his workspace copy.

For example, if a user wishes to create a single-stage-to-orbit (SSTO) vehicle. He could open a project containing the 100K class of vehicles and copy the vehicle into a new workspace. Along with that vehicle would come several other objects, such its engines, subsystems, their process flows, and associated resources. If he wishes, the user can replace these previously modeled components with components from other project sources. This process of selecting and modifying components allows the user to create the desired vehicle configuration; in others words, creates a new class of vehicle complete with its components - elements, systems, subsystems, and their parts. In a specific example, the user may wish to convert his experimental Delta Clipper (DC-X) into an X-33 by replacing the DC-X's 4 RL10 engines with 6 Space Shuttle Main Engines.

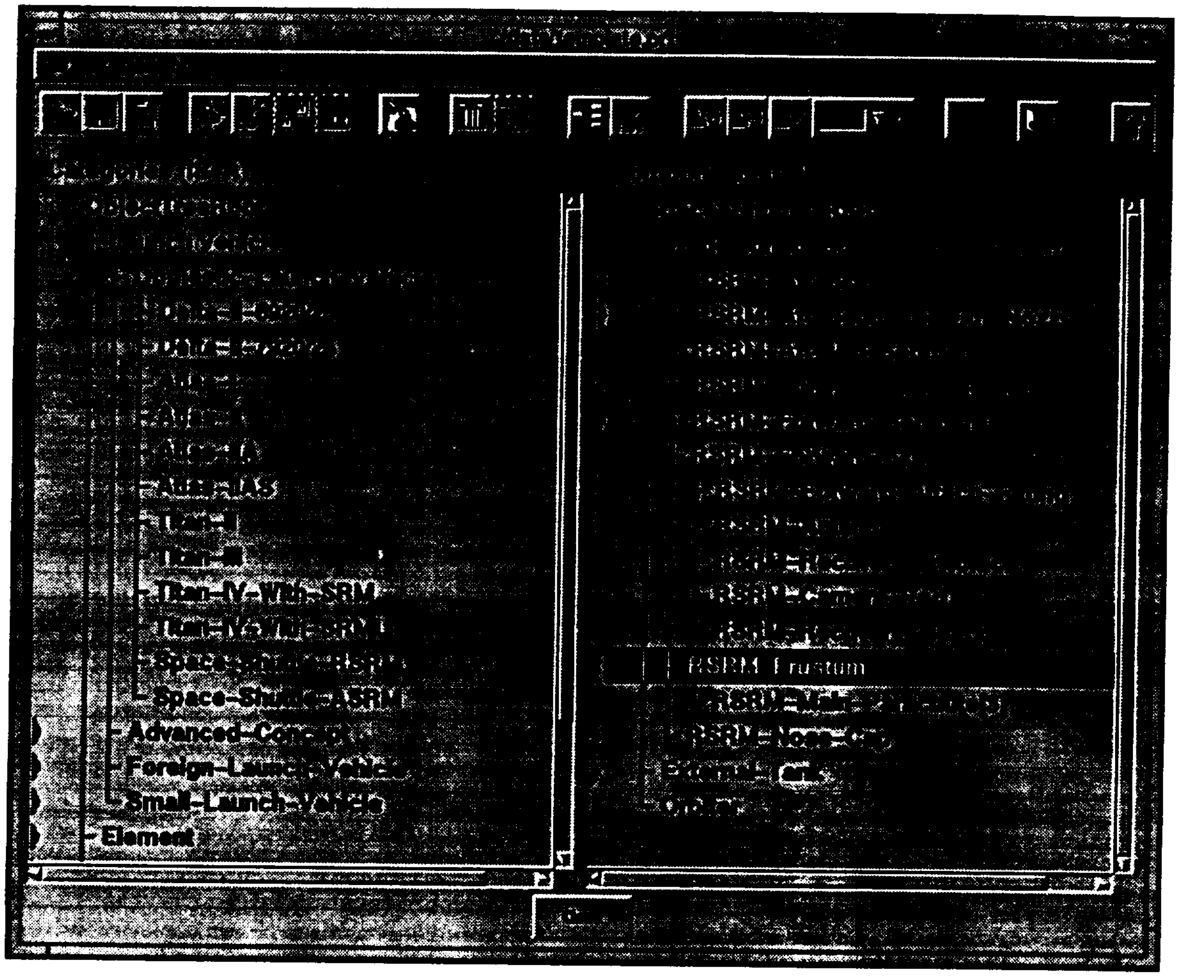

Figure 3-2: Vehicle Definition Assistant Displaying both Categories and Components

3.2.2.2 Operations Definition Assistant (ODA)

The OIA also provides an operations definition assistant to help the user define and select appropriate launch site operations for the vehicle. The operations definition assistant will include user interfaces for *process flow definition*, *resource requirement definition*, *temporal constraint definition*, and *assessment setup*.

Process flow definition. The process flow definition interface allows the user to define appropriate process flows for the vehicle and its components. A vehicle or any of its components can own process flows to be performed at the launch site. These flows are read into the workspace at the same time that a component is read in. The user may create or select process flows that are applicable to the vehicle he is defining. Any flow can then be modified to create different or more detailed flows based on other component flows, or from its subcomponent or subsystem flows.

For example, If the user has specified subsystems for the Orbiter that differ from the template library Orbiter definition. He may wish to construct a different Orbiter OPF processing flow by integrating the new subsystem flows into the OPF processing flow and eliminate the old subcomponent flows. Figure 3-3 shows a sample process flow displayed in the ODA.

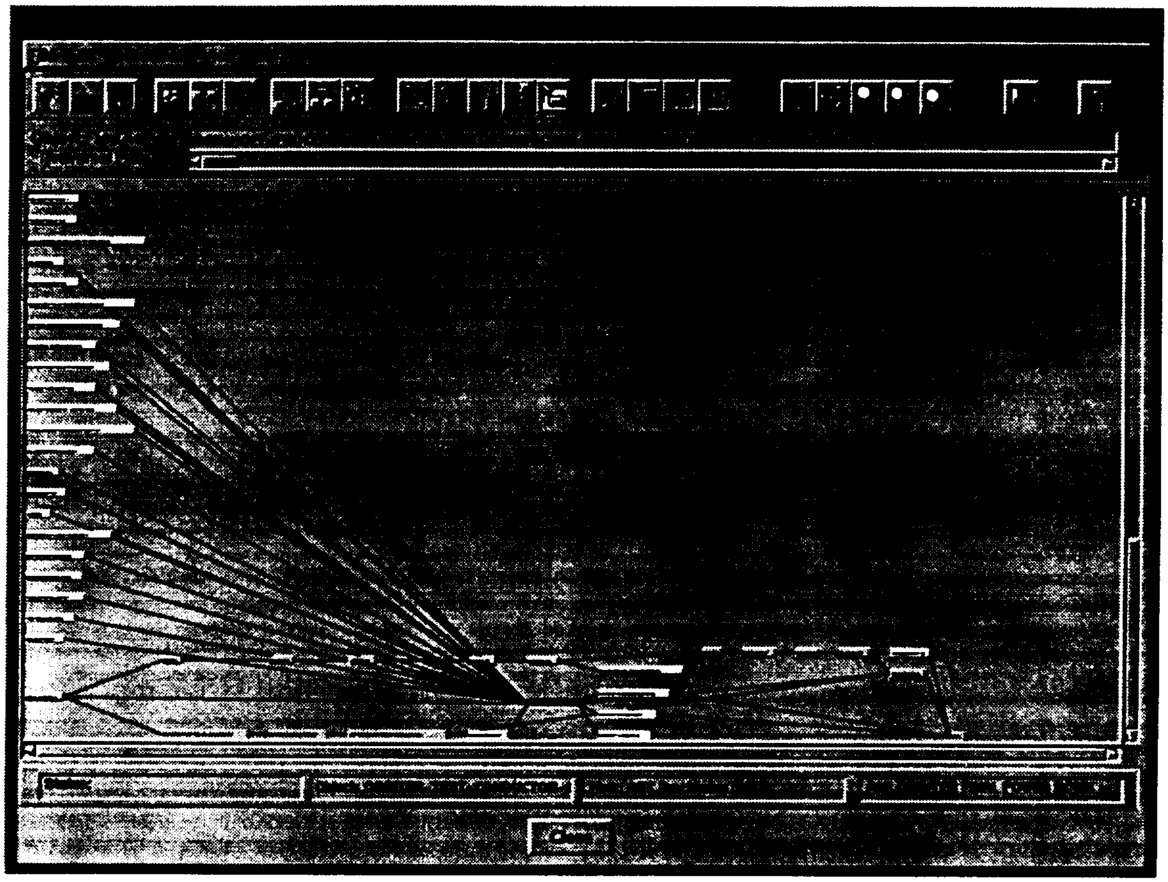

Figure 3-3: The Operations Definition Assistant

Resource requirement definition. The resource definition interface provides a method for specifying the objects needed to accomplish the current activity. Any object in the workspace could possibly be a resource. Furthermore, each object in the workspace, which is intended to be used as a resource for an activity, should specify the maximum number of units available in order to detect conflicts in resource usage.

Temporal constraint definition. The temporal constraint definition interface provides a method for specifying how two activities occur together in time. That is, whether they start at the same time, finish at the same time, or one starts when the other finishes. The interface also provides the ability to specify delay's between activities. An example of the dialog used to edit resource requirements and temporal constraints is shown in figure 3-4 below.

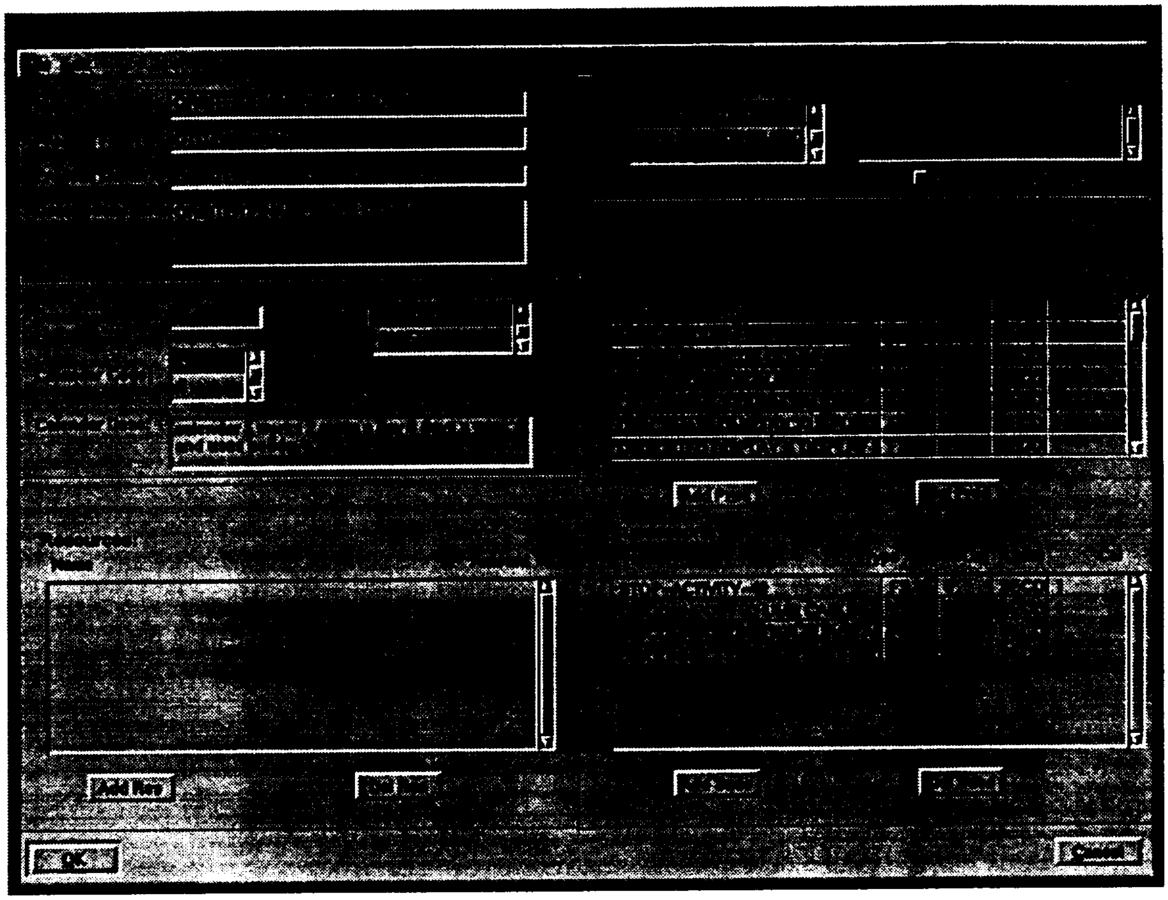

Figure 3-4: The Activity Editor

Assessment setup. The assessment setup provides a method for selecting the launch vehicle and processing flow that is to be assessed. The customer indicated that the OIA was primarily intended to assess a single flow of a given vehicle, but multiple flows assessments are supported. Each flow selected requires that the user indicate whether he wishes to anchor the start or finish of the flow, and the date the flow is supposed to start or finish.

3.2.3 Analysis Engine

The OIA also provides an *analysis engine* to aid the user in assessing the ability of the launch site to support the vehicle processing that has been modeled. The analysis engine makes use of the operations definition knowledge base and displays its results through the reporting utilities. The analysis engine determines the start and stop times for each activity based on whether the flow was anchored at its start or finish in the assessment setup dialog show in figure 3-5 below. If the start of the launch vehicle's flow is anchored, all activities are assumed to start as soon as possible. If the end point is anchored, then the scheduler assumes each activity starts as late as possible.

As the scheduler completes its final pass through the activities being scheduled, it performs two tasks. First, it sets each activity's start and stop times (e.g. early start, early finish, late start, etc.). Secondly, for each resource required to complete the activity, the resource allocation engine records the current activity's time interval in each resource's usage data structure. Each resource is assigned based on the activity's ASAP or ALAP interval preference.

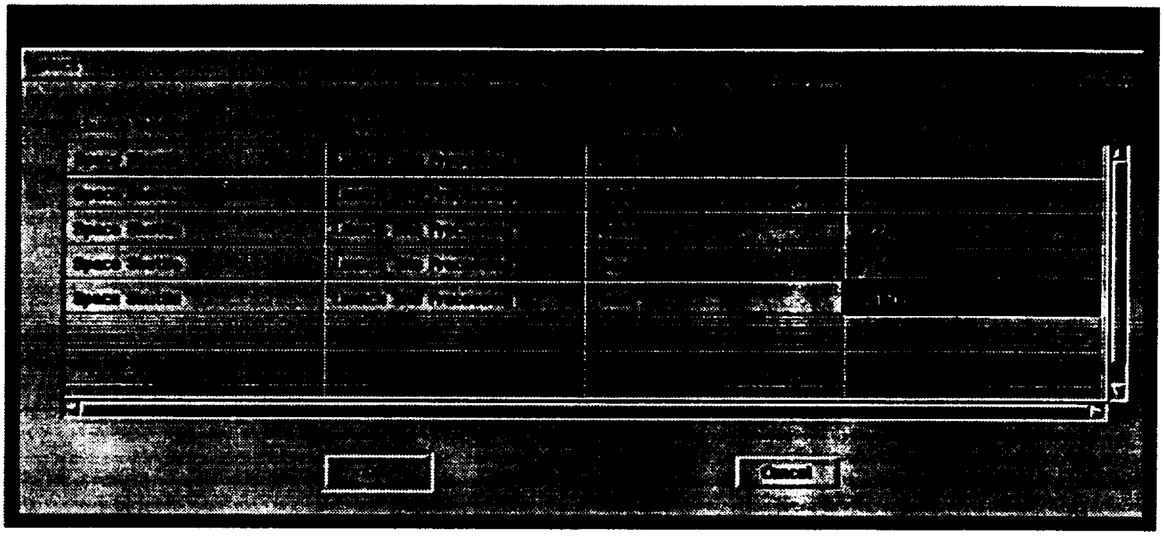

Figure 3-5: The Assessment Setup Dialog

3.2.4 Reporting Utility

Once an assessment has been run, we provide three graphical reporting utilities that display results on either the screen or a to printer. For examplé, Figure 3-6 shows a Gantt chart of processing activities and Figure 3-7 shows a profile of a resource used during an assessment. The reporting interface also provides menu options that allow the user to save assessment results to a disk file in Microsoft Project's MPX 3.0 format. Menu options and scrollable lists prompt the user for the filename and location where the file is to be saved on the disk.

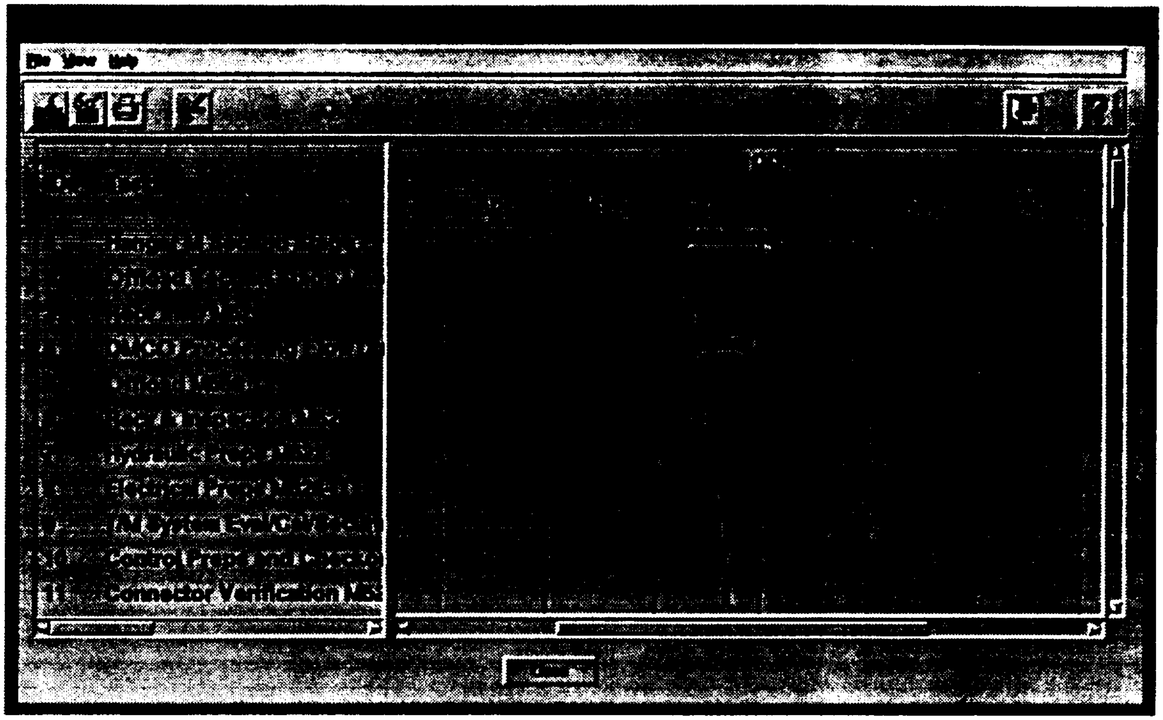

Figure 3-6: Task Gantt Chart Report

We also have the ability to specify particular limits on the number of resources available. In Figure 3-7 below we show a usage profile of the Mechanical Technician skill category. We have set an arbitrary limit on the number of mechanical technicians available in our resource pool at a level of four. Any time that the allocation goes above this limit, we display that allocation in red.

3.3 Implementation

All of the software developed under this contract was written in the C++ programming language. The object-oriented software community has long claimed that a marked improvement in code reusability can be achieved by adopting an object-oriented development strategy. Now that it has been six years since we first began traveling down this path, we are now beginning to realize this claim.

3.3.1 Windowing System Layer

At the mid-point of the project, we made a critical decision to switch from the popular X-Windows/Motif user interface to a proprietary windowing system called Galaxy, offered by Visix. The choice was motivated by the fact that they had a C++ object-oriented implementation that was available on most popular UNIX workstations and personal computers like Apple's Macintosh and Intel-based DOS/Windows PC's. This would allow us to port our software to new computing platforms simply by recompiling the source code. As it turns out, we made use of this facility by developing all of our software on Sun SpacStation 10's and simply recompiled the source code on a Digital

DecAlpha workstation. Our implementation has tried to conform to the most recent trends emerging in new products. The interface design and implementation represents a significant improvement over our previous graphical user interface, like that of the Ground Operations Simulation Technique (GOST).

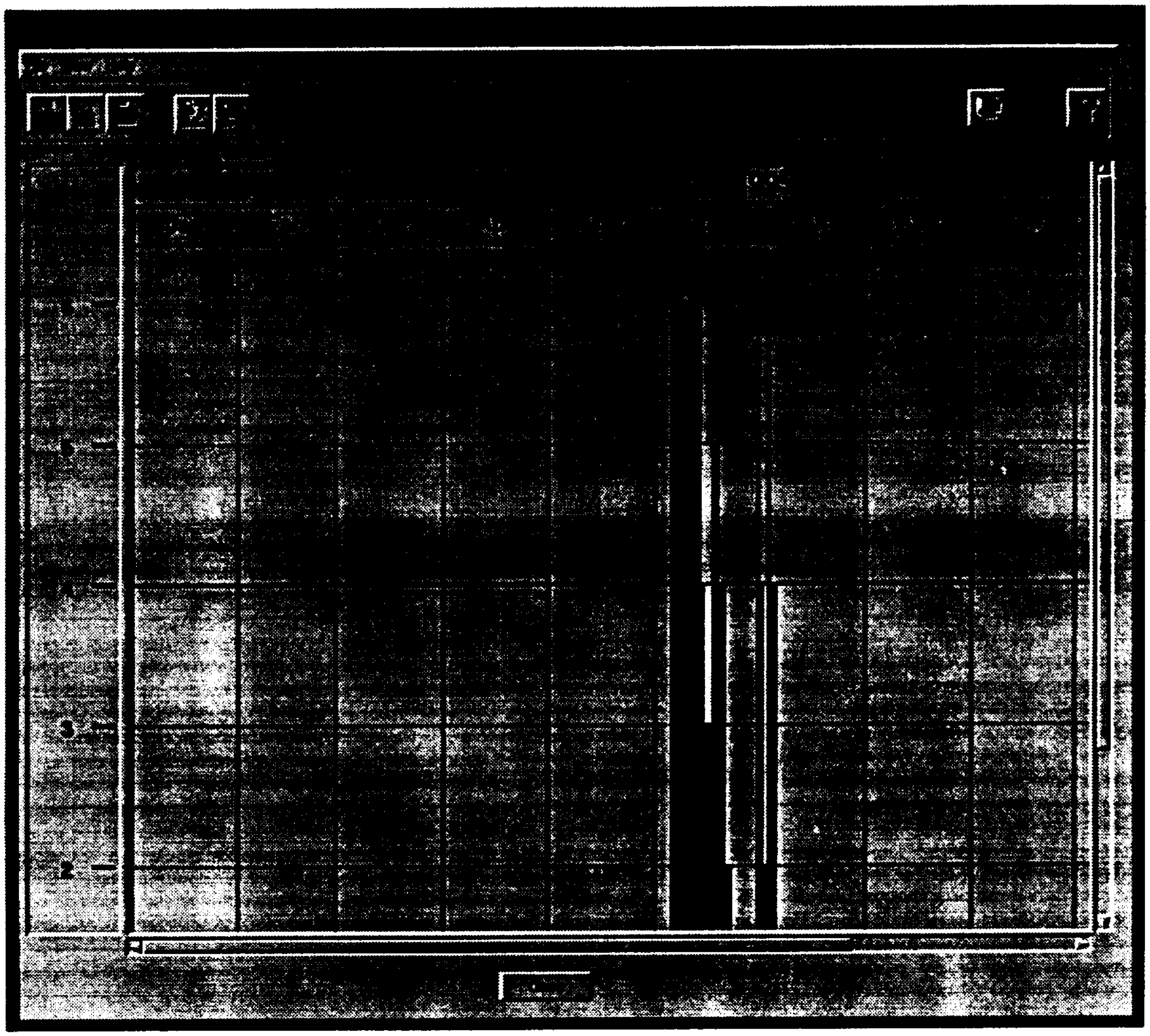

Figure 3-7: Resource Histogram Report

3.3.2 Server Layer

The Model Management layer described in section 3.2.1 was implemented in such a way that it could easily be encapsulated by a process running on a network file server. This will allow a workstation on the network to act as a client display processor, and the MMU process would act as the server. This decoupling will prove useful in the future as distributed computing becomes more of a reality.

The Workspace Manager controls user access to information contained in the various open knowledge bases through the Knowledge Representation System (KRS). While the

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OIA contains version 1.0 of the Workspace Manager, we have spent a number of years developing the KRS component. The KRS is currently at its fourth version, and has stabilized very nicely. We believe that this architecture is of sound design and can readily support the addition of true database capabilities. As mentioned in Section 3.2.1.5 above, we are not aware of another implementation of this type or capability that exists. We have done extensive research to substantiate this fact and believe that our work in the model management utility is of most value from a scientific point of view.

3.4 Validation

The validation phase verified that the OIA software performs as designed and that the vehicle processing model assessment results are valid. Two types of validation were performed: *software testing* and *model results testing*.

3.4.1 Software testing

Both unit testing and integration testing were performed. Each software module or unit was subjected to one or more test cases to determine that it meet its public interface and functional obligations to the rest of the system. Modules that interface with each other to perform a function were tested as integrated units. This integration testing was conducted at increasingly higher levels until the entire system was tested. This bottom-up testing approach was employed to help eliminate hidden "bugs" and to verify that the software executes the intent of the design. However, we have identified a number of known bugs in the system. As with all off-the-shelf software development, the project completion date comes before everything can be completed to the satisfaction of the software developers. These bugs are all minor, but we do recommend that users save their work often to prevent significant loss of data in the event of a catastrophic application error.

3.4.2 Model results testing

The OIA system was also validated against a known launch vehicle, the Delta-II, and studies to verify that it produces expected results were performed. We also developed a test that stresses the OIA capabilities by importing the Orbiter's OPF activities from Artemis. Unfortunately, the data provided by Lockheed was incomplete and did not allow us to perform assessments against it, but did provide a complex dataset from which to exercise ODA modeling capabilities.

In conclusion, we believe the Operations Impact Assessor meets the goals of the NASA Research Announcement contract. It certainly offers an innovative computer-aided solution that pushes the state of the art in managing multiple knowledge bases within the C++ object-oriented programming language. We also believe that it provides an excellent means for centralizing study data form various conflicting sources into a consistent repository from which engineers can extract data. Furthermore, we believe the tool meets the need to perform assessment quickly. While the scheduler may not support the exact fidelity required, it is sufficient for a quick-look assessments. Our robust export facilities should enable other tools to be used to refine our schedules and resource data if necessary.

4.0 TASK 2 - OPERATIONS ANALYSIS OF LAUNCH VEHICLE CONCEPTS AND DESIGNS

4.1 Task Overview

Analyses of launch vehicle concepts and designs for operations, facilities, GSE, and manpower were performed to make launch site considerations available for vehicle design processes. Key launch site drivers were identified, detailed assessments of these drivers were made, and design goals were developed. A stand-alone document entitled "Launch Site Operations Design Data Book" was developed which satisfies the study Task 2 deliverable item. It contains, in full, a description of the research conducted, task results, discussion of results, and the launch vehicle design checklist.

4.1.1 Purpose

Certain attributes of flight hardware design determine the ease of launch site processing. Those attributes that accommodate ease of processing typically require fewer launch site resources. The advent of reusable launch vehicles and increased budget pressure to decrease life-cycle costs require emphasis on ease of processing to lower launch site costs. In this task, those design characteristics that lend themselves to ease of processing and lower operational costs have been identified. The Launch Site Operations Design Data Book is useful to designers, project managers, and program managers from the conceptual studies phase through flight hardware development phases. Additionally, it is intended as a reference document for launch site personnel who are assessing new or updated launch vehicle concepts proposed by design centers. These assessments are performed using conventional manual methods or advanced modeling techniques such as the OIA which was developed in Task 1.

Launch operations tend to be complex and time-consuming because vehicles have been designed to achieve high performance rather than rapid, inexpensive launch turnaround. Many times there are several designs that are of equal cost and satisfy mission requirements equally as well. In these cases, it is prudent tó choose the design that will lower operational costs. If the cost drivers are not understood, new launch system are likely to inherit the same cost drivers of today's system. For example, a close relationship exists between vehicle pad operations and payload accommodation and design costs. By designing for abbreviated pad processing, payload pad access requirements may be reduced or eliminated. Thus, significant savings can be realized in support equipment and recurring operational costs. The Launch Site Operations Design Data Book will help design personnel to identify the lower operational cost designs. The data book presents operational impact data to aid management develop trades between design considerations and operational drivers. It must be remembered that the vehicle design recommendations are not to be regarded as requirements. Launch site operability must be traded against performance and design and development costs. But these recommendations and rationale for them must be given due consideration.

There is a wealth of documentation providing specifications for design of launch vehicles such as mil specs and safety standards. It is not the intent of this document to repeat design criteria, but to present design goals for improved operability at the launch site.

4.1.2 Scope

Task 2 results are applicable to the design process for reusable and expendable launch vehicles. It addresses all launch vehicle elements including boosters, core stages, crew systems, and the interface with payload elements. All launch vehicle systems were considered, but focus was on several high-impact launch vehicle systems which are key launch site drivers. Due to funding and time limitations, the primary area of research centered on Shuttle systems.

4.1.3 Approach

The approach used for Task 2 is shown in Figure 4-1. The first step was to identify high impact areas. Launch site operations cover a wide scope. To cover the gamut, enormous resources could be consumed to develop design recommendations. Through selection and assessment of high impact areas, maximum benefit was realized.

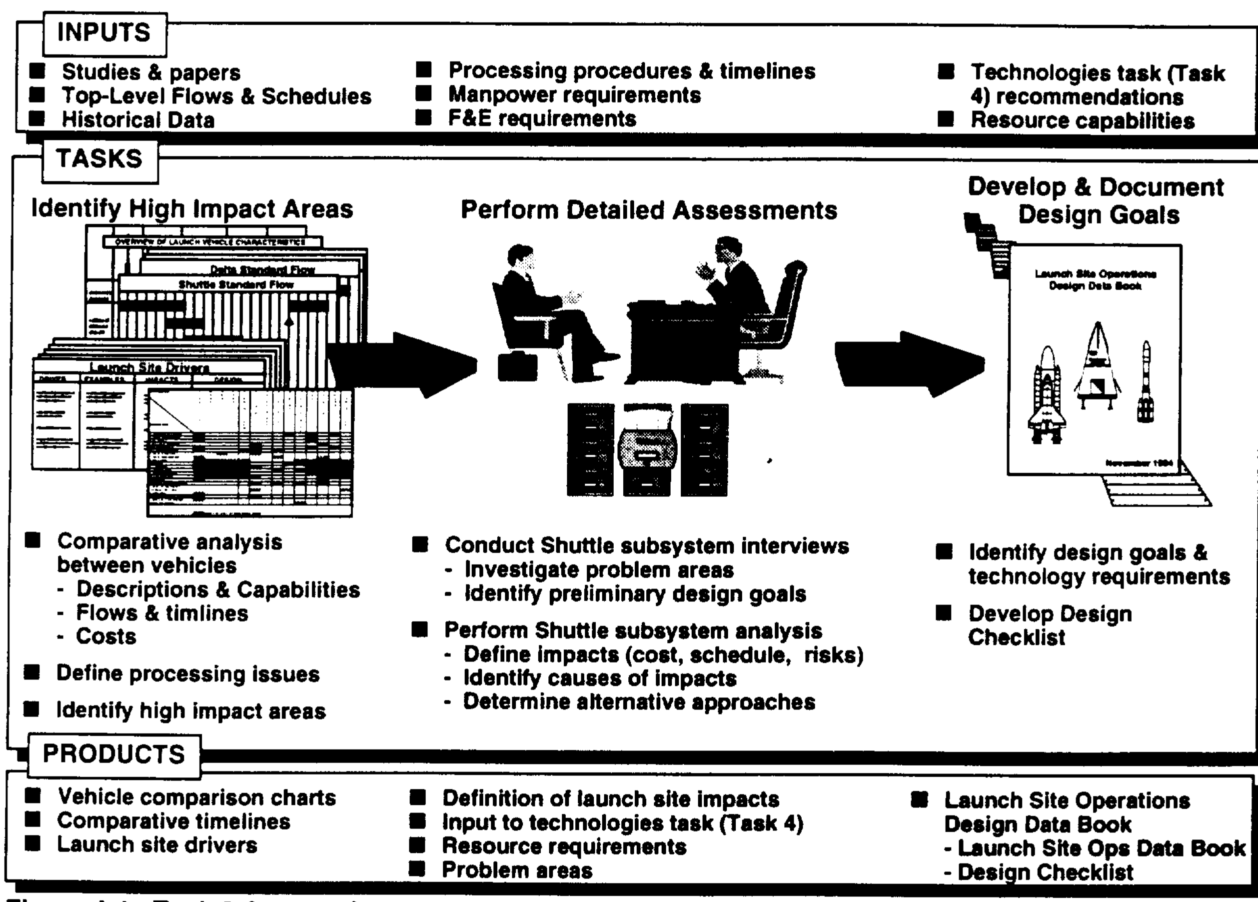

Figure 4-1 Task 2 Approach

A review of launch site operations, comparison of different launch vehicle processing flows, and review of documented launch site problem areas provided the basis for the initial identification of high impact areas (See Appendix A of the design data book).

The Shuttle launch system (Orbiter, External Tank, Solid Rocket Boosters) was selected as the vehicle for detailed performance assessments and as the gauge for operability of designs. The Shuttle was selected because (1) it is a complex amalgamation of the full range of launch vehicle systems (including manned systems); (2) it is the most advanced of all launch vehicles with which KSC has extensive experience; (3) there is ready access to extensive data; (4) collection of data was useful for verification of the OIA; and (5) Shuttle data is most relevant for KSC assessment of future launch vehicles.

In the second step of the approach, data was collected from NASA shuttle subsystem experts. This data included a description of the launch site processing, facilities used, launch site drivers, manpower and GSE requirements. In addition, data concerning flight hardware and GSE planned and unplanned work, operability assessments, problem areas, suggested improvements, and alternate systems and technologies were collected. In the third step, these data for each subsystem were entered into a data base, the data were then analyzed, and a time-phased design checklist was developed.

4.2 Summary of Findings

Table 4-1 maps the launch site processing issues to the Shuttle system involved. Identification of issues resulted from either input from subsystem experts or from data analysis. Table 4-2 provides a summary of the launch site operations drivers and vehicle design recommendations to improve operability. This is a summary of the design checklist items contained in Appendix C of the data book. The table provides a reference to example hardware characteristics that need change for improved operability and states the impact resulting from the launch site driver. It is recognized that the recommendations to improve operability have been made without regard to flight performance. Operability over the life of the vehicle must be weighted against performance within design trades.

Table 4-1 Launch Site Operations Design Issues Mapping to Shuttle Systems

■ Launch site processing issue

Launch Site Operations Design Issues \ Shuttle System	Communications & Tracking	Crew Systems	Data Management System (DMS)	Guidance, Navigation & Control (GN&C)	Landing Systems	Payloads Interface	Power	Propulsion	Separation Systems	Structures & Mechanical	Thermal Control & Protection	Ground Support Equipment (GSE)
Operability												
Accessibility	■		■	■	■	■	■	■	■	■	■	
Availability			■	■				■		■	■	■
Maintainability	■	■	■	■	■		■	■		■	■	■
Reliability	■		■				■	■		■	■	■
Supportability	■	■	■	■	■		■	■		■	■	■
Launch Site Driver												
Hazardous Materials							■	■				
Multiple Propellants								■				
Toxic Propellants					■			■				
Ordnance Devices									■			■
Low Reliability Fluid Interfaces							■	■			■	
Complex/Extensive Assembly & Test						■	■	■		■		■
Lack of Vehicle Autonomy	■					■						
Lack of Robustness					■			■			■	
Lack of Standardization												■
Hydraulic Systems					■			■				
Environmental Sensitivity					■	■		■			■	
Hardware Transport		■						■				
Changing Configurations												
Unique Facilities	■							■				
Complex/Unique Processes												
Complexity								■				■
Fragile Materials										■	■	
Support Requirements												
Extensive Manpower						■	■	■		■	■	■
Extensive GSE							■	■		■	■	■

Table 4-2 Summary of Launch Site Operations Drivers & Vehicle Design Recommendations to Improve Operability

* Applicable primarily to reusable vehicles

Key Launch Site Driver	Examples	Impacts on Operations	Vehicle Design Recommendations to Improve Operability
Hazardous Materials	Ordnance devices, propellants (cryogenic, toxic) high pressure gasses, radioactive devices, cleaning agents, solvents	Specialized facilities, equipment, limited personnel access, stoppage of other work, specialized training, more complex procedures (development, review, & approval process), environmental impact assessments and regulations	• Trade requirements for hazardous systems/systems requiring hazardous servicing against increased operations efficiency • Limit hazardous materials • Limit vehicle propellant loading to the launch pad • Minimize requirements for integration facilities to handle hazardous materials (such as the VAB)
Multiple Propellants Handling	Use of different propellants for main propulsion, boosters, reaction control systems, auxiliary power units	Additional systems maintenance, operations & training; multiple and separate propellant loading, various hazard levels, various purge systems, various equipment requirements, additional systems maintenance, operations, & training	• Use common set of propellants (oxidizer & fuel) for all (RCS, ACS, main propulsion) propulsion systems
Toxic & Environmentally Unfriendly Propellants	UDMH, MMH for reaction control systems, Orbiter Maneuvering System, auxiliary power units; Complicates postlanding operations	Costly life support equipment, other work stoppage, special and additional safe explosion-proof facilities & equipment, specialized processes, procedures, & training	• Eliminate hypergolic systems (toxic propellants)
Ordnance Devices	Separation systems, destruct systems, appendages/actuators release, landing gear deployment	Increased hazard levels, other work stoppages, specially trained personnel	• Provide laser-initiated ordnance devices or other safer ordnance systems • Use latch-type devices when appropriate
Low Reliability Fluid Interface Connections	Cryogenic system joints, QDs, engines; Extensive hazard warning system required to detect leaks.	Extensive leak testing, leak isolation	• Provide leak-proof cryogenic seals, connections, QDs and engines • Minimize use of QDs • Manifold sensors in plumbing • Use multi-function, multi-range sensors to reduce number of possible leak sources
Fragile Materials	Thermal protective systems (e.g., shuttle tile, External Tank), structures (e.g., boron-Al struts) tankage (balloon tanks), thermal radiators, windows	Increased time to work around, protective equipment, damaged hardware, launch delays, extensive maintenance and repair	• Provide robust hardware to withstand normal operational environment rigors • Eliminate forward-facing windows

Table 4-2 Summary of Launch Site Operations Drivers & Vehicle Design Recommendations to Improve Operability (Continued)

Key Launch Site Driver	Examples	Impacts to Operations	Vehicle Design Recommendations to Improve Operability
Low Reliability	Flight & ground systems requiring extensive test, maintenance & removal/replacement	Increased unscheduled maintenance, repair, testing, launch delays & trouble shooting	• Highly reliable hardware (flight & ground test)
Complex & Extensive Assembly & Test Requirements	Booster segment assembly, engine-to-core/boosters, payloads, field joints, water recovery; ECLSS, fuel cell testing; extensive LPS support requirements; extensive/complex payload handling, integration and test	Handling, assembly, & test, GSE, & documentation requirements, problem reports & discrepancies, potential damage to flight hardware during moves and/or lifting	• Perform maximum integration & test possible at factory (Ready to Fly) • Minimize field joints • Provide simple, fool-proof self-aligning, rapid assembly flight hardware • Design to permit rapid reconfiguration, disassembly, and reassembly (e.g., F-18 ordnance reconfiguration & engine removal * • Minimize disassembly requirements postflight * • Provide simplified/reduced payload interface • Minimize verification procedure requirements • Provide automated systems test capability • Provide capability for flight instrumentation checkout without powering up entire vehicle • Use fly-away ground interfaces rather than T-0 umbilicals.
Lack of Vehicle Autonomy	Lack of BIT/BITE (fault detection & isolation to LRU), Health monitoring systems, expert systems diagnosis, ground support of initial launch phase; extensive LPS support required	Time required for test, test equipment, test set-ups, range safety & control & supporting infrastructure, GSE requirements, disassembly for hardware	• Provide electronic health and status monitoring • Provide subsystem self-monitoring , recording & RF link to ground units • Provide on-board navigation (trajectory, velocity) assessment
Lack of Vehicle Robustness	Ability to fly and complete mission with known faults/failures vs shuttle that routinely flys at 109% rated thrust, landing gear, brakes	Increased need for testing, fault isolation, repair, and maintenance during time-critical operations	• Design for normal operations well below design limits with contingency capabilities to operate at or beyond design limits

Table 4-2 Summary of Launch Site Operations Drivers & Vehicle Design Recommendations to Improve Operability (Continued)

Key Launch Site Driver	Examples	Impacts to Operations	Vehicle Design Recommendations to Improve Operability
Lack of Serviceability	Propellants, consumables, payloads, flight crew equipment, Payload late/early access (e.g., Spacelab vertical access), payload serviceability (lens caps, batteries)	Manpower requirements, access GSE, servicing GSE, timelines, stoppage of other work for servicing	• Design for ease of access to servicing locations & controls • Provide common propellants, purges & other fluids • Provide embedded practical sensors for fluid systems
Poor Accessibility	Ample access for hardware systems requiring routine access, servicing ports (field joints, servicing, LRUs) not provided; Orbiter Maneuvering System pod test and maintenance must be performed off vehicle	Increased timelines, complex and hazardous operations, increased manpower, specialized GSE, hardware damage. Disassembly of hardware required for access to repair/maintenance/servicing areas which cause damage to critical hardware.	• Provide "arm-reach" access for routine operations including postlanding servicer connections • Provide element internal access capabilities as part of flight structure • Keep access areas clear of hardware easily damaged (e.g., cables/sensors near step areas, sensitive structures) • Provide rapid open & close access panels • Provide access to LRUs without removal of other hardware • Provide LRUs with handling features *
Low Maintainability	Hardware requiring periodic maintenance on a routine basis, LRUs, Orbiter flight deck	Increased risk to flight hardware, increased timelines, manpower requirements, GSE spares	• Provide for ease of hardware R&R (quick-change components not requiring specialized equipment), inspection, and servicing • On-board automated fault isolation to the LRU level • Reduce maintenance requirements and minimize down-time for maintenance * • Provide vehicle health maintenance systems to predict incipient problems * • LRU changeout by minimum manpower & support
Low Spares Availability	Cannibalization, lack of commonality of parts intra & inter systems, use of unique hardware when off-the-shelf hardware is acceptable	Increased risk of hardware damage, increased manpower & test requirements, increased spares costs and availability, wear & tear on hardware	• Provide common hardware specification, design, & procurement • Increase reliance upon off-the-shelf hardware

Table 4-2 Summary of Launch Site Operations Drivers & Vehicle Design Recommendations to Improve Operability (Continued)

Key Launch Site Driver	Examples	Impacts to Operations	Vehicle Design Recommendations to Improve Operability
Lack of Standardization (Unique Hardware & Software)	Lack of commonality between similar-function flight and ground hardware, unique ground and flight software, unique designs when off-the-shelf hardware could be acceptable	Decreased system responsiveness to respond to manifest perturbations and flight hardware problems, extensive software development and verification process	• Provide standardized off-the-shelf hardware, software, and GSE • Minimize need for unique tools and handling equipment • Standardize payload integration hardware and configuration in the payload compartment and flight crew areas.
High-Maintenance	Engine leak, functional testing, maintenance procedures; ECLSS systems tests; fuel cell single cell tests; extensive LPS support; Orbiter Maneuvering System pods removed during most postlanding processing	Major expenditure of launch site resources, disconnection of fed lines and valves to perform leak and functional tests leading to contamination and inducing leaks in the system	• Simplified, robust propulsion system • Less sensitive start requirements (thermal conditioning, valve timing) • Highly-reliable cryogenic seals to minimize or eliminate need for leak checks • Extensive development testing to eliminate problems and increase reliability • Provide built-in pressure and flow rate sensors
Hydraulic Systems	Aero control surfaces, propulsion gimbaling, landing gear actuators, nose wheel steering, brakes requiring auxiliary power units; SRB hydraulics	Increased test, check out & maintenance requirements, additional system components	• Use electro-mechanical and electro-hydraulic actuators • Use engine pump shaft power take-off for TVC electrical power supply
Unique Facility Requirements	Very large or tall facilities, clean rooms, hazard-compatible systems	High development and outfitting costs, high cost operation and maintenance	• Limit hazardous materials handling requirements • Employ single integration & launch facility approach • Maximize use of existing facilities
Environmental Sensitivity	Lightning, rain, wind, high temperatures, contamination.	Launch & landing delays & scrubs, work delays, dictates time of operations, coatings on flight hardware & GSE, contamination control and removal from launch vehicles and payloads, thermal protection systems coatings, alternate landing sites	• Minimize exposure of element-sensitive components • Select non-corrosive durable materials insensitive to launch site environment • Minimize hardware cleanliness requirements • Minimize flight hardware sensitivity to lightning • Design for flight envelopes within launch & landing site weather norms

Table 4-2 Summary of Launch Site Operations Drivers & Vehicle Design Recommendations to Improve Operability (Continued)

Key Launch Site Driver	Examples	Impacts to Operations	Vehicle Design Recommendations to Improve Operability
Hardware Transportation	Intra-site system, element, launch vehicle transfers, post-landing transportation back to launch site.	Transportation equipment, interface testing, reconfiguration of hardware, software, & GSE, timeline increases, personnel TDY	• Eliminate hazardous systems requiring off-line processing • Minimize post-landing disassembly * • Adopt single integration & launch facility approach • Design for landings to accommodate most weather patterns *
Changing Configurations & Requirements	Assembly, test, maintenance, servicing, design	Changes in documentation, & GSE	• Limit changes to "make safe" and "make operational" • Perform "block" changes during overhaul/refurbishment periods * • Provide standard payload interfaces to eliminate configuration changes.
Complex or Unique Processes	Shuttle TPS installation/ repair, water recovery operations	Unique procedures, specialized training, complex parts tracking, unique equipment	• Design systems for industry standard processes & procedures • Avoid water recovery hardware * • Avoid parachute recovery *
Flight Hardware Complexity	RSRBs with 75k parts & components (5k removed, inspected & replaced after each flight; 31k tile on orbiter; 250k electrical connections on orbiter; 8k connectors; SSMEs vs RL-10 engines; complex payload interfaces	Increased ground processing timelines, hardware problems, documentation, maintenance, & test requirements	• Minimize use of cold plates for avionics cooling • Eliminate hardwire connections where possible and use MIL-STD-1553 interfaces • Trade life cycle costs against hardware throw-away costs * • Reduce payload active interfaces to vehicle

4.2.1 Manpower Requirements

Engineering manpower requirements were collected (rather than technician, quality, or other skill requirements) because the data was readily available, it provided a different perspective on the manpower requirements than other research of this type, and engineering manpower appears to be more stable in times of personnel reductions. In addition, unlike other skills, few engineers are shared between systems by either NASA or its contractors (making it clear which personnel are tied directly to a subsystem). The data collected was for support of eight Shuttle missions per year. It is difficult to predict the engineering manpower requirements for different launch rates. Some of the workload is launch rate-independent such as the production of procedures, implementation of hardware and software changes, and similar activities. Some groups function as the minimum manpower required to support a single flow. The engineering manpower level is probably tied closer to the number of launch vehicles in the fleet than to any other factor.

The total SPC labor hours in 1993 for processing one mission was about 700,000 hours. Within this research, the total Shuttle Processing Contract (SPC) engineering manpower supporting eight missions per year was found to be 119 engineers (1.2 million hours) or 152,000 hours for one mission. This would indicate that the engineering force averages about 22% of the total manpower requirement for mission processing, falling within range of other study results. In addition to the manpower accounted for in this research, other personnel skills and services such as launch site support, facility engineering, security, medical, fire, corporate management, Human Resources, administrative services, and logistics must be added not only to the contractor workforce but also to the NASA engineering headcount.

The average engineering headcount for a Shuttle subsystem was found to be 28. This provides an indication of those systems which are manpower drivers and ones that should receive attention to determine the cause and appropriate remedy. Figure 4-2 shows those subsystems requiring engineering headcount greater than the average.

The unplanned flight hardware work and work required to maintain GSE is often overlooked in estimating manpower requirements. Planned work is all work defined and scheduled prior to the start of a flow. Planned work is associated with standard and periodic operations and maintenance requirements, deferred work from a previous flow, flight system modifications, requirements change notices, special requirement, and flight system modifications. Unplanned work is defined as work generated as a result of Discrepancy Reports (DRs), Interim Problem Reports (IPRs), Problem Reports (PRs), and Type B TPSs (non-configuration changes). The average fight hardware unplanned work was found to be 15% of the total headcount. Maintaining the GSE and readying it for operations was found to be 37% of the total workload. Unplanned GSE work was found to be 5% of the GSE work. Although many subsystem personnel complained about the age of the GSE and that it is prone to failure, overall, the percentage of unplanned GSE work is fairly low. The report Magnitude and Impact of Unplanned Activities on Shuttle Processing states that per the Shop Floor Data Collection System (records technician manpower per subsystem), unplanned work accounts for 40% of the processing manpower. This is about double the findings shown in Table 4-3.

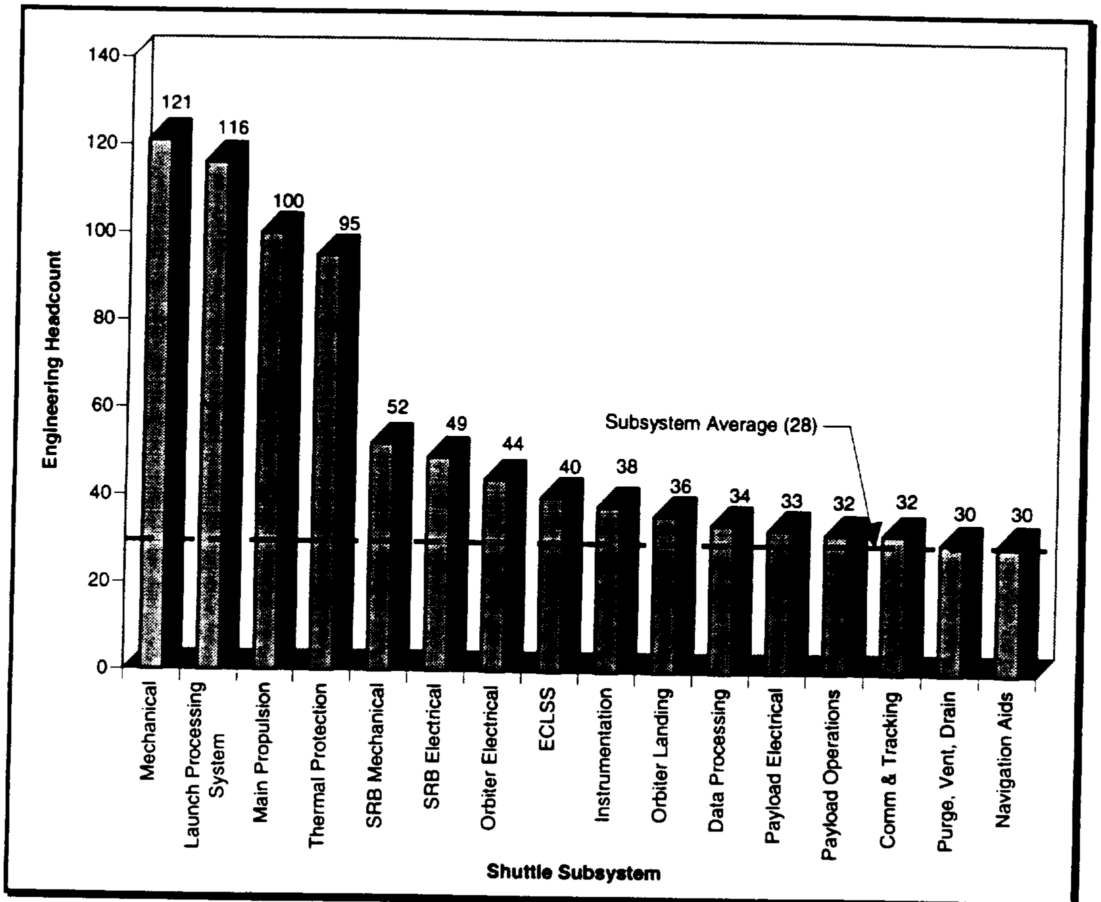

Figure 4-2 Engineering Manpower per Shuttle Subsystem (above average)

By count of PRs processed for GSE and flight hardware (Figure 4-3), it would appear that the unplanned GSE work should be greater than the unplanned flight hardware work. The disparity can be accounted for in that typically the flight hardware PRs require more time for coordination and disposition than GSE PRs.

4.2.2 GSE Tally

Four categories of GSE were identified: fluid, handling, access, electrical, and other GSE. "Other" GSE included items such as tools, hardware covers and caps, and specialized containers. The number of types and total units were collected for each category. The data contained in the Ground Support Equipment Maintenance Plan provided the basis for many of the inputs, with the Model Number from this document indicating an individual unit. Figure 4-4 shows the allocation of the GSE to Shuttle systems and Figure 4-5 shows the makeup of the GSE across the GSE categories. Those subsystems which had a high percentage of GSE work correlated to a high count of GSE units in only 11 out of 19 instances. Of those 11 subsystems, seven had a higher than average number of fluid GSE units. Complaints from the subsystem experts concerning fluid GSE included long setup times, sampling requirements, failures, and flow measurement problems. The lack of strong correlation between high GSE workload and high numbers of GSE may indicate that although larger numbers of GSE will drive some program costs (e.g., initial program procurement costs, facilities for storage of GSE, and GSE maintenance) they do not

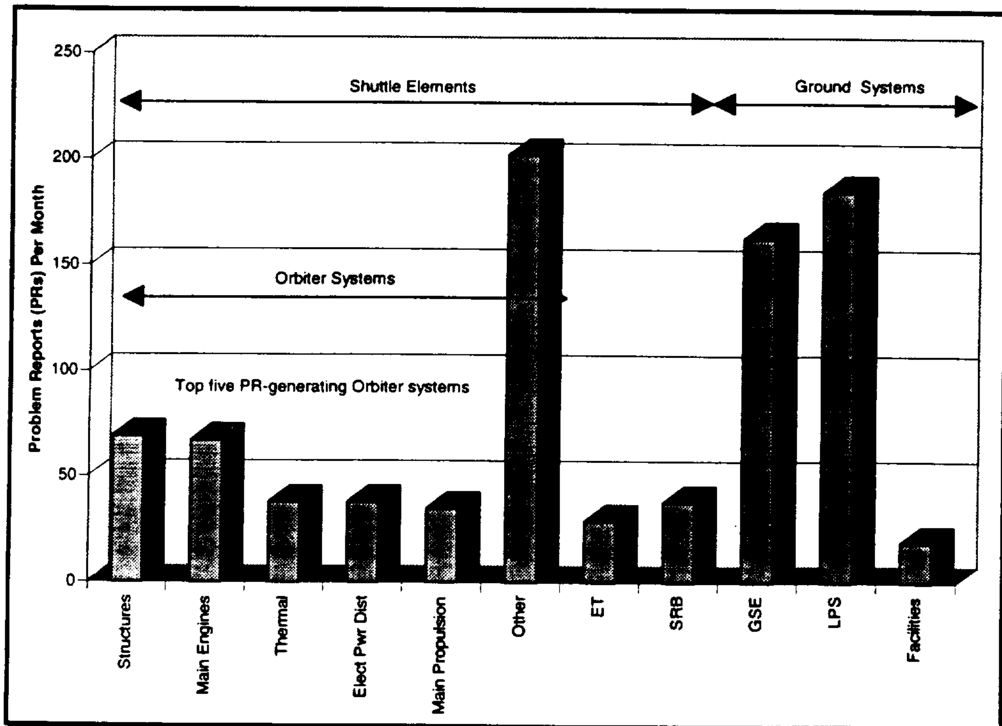

Figure 4-3 Fight Hardware and GSE Problem Report Traffic (Fiscal Year 1993) average

significantly add to the launch site workload and in some cases may actually decrease workload (proper tools or equipment provided for the job). Conclusions that can be drawn from the high number of GSE items are that there is little GSE commonality and there are few instances of off-the-shelf/standardized processing equipment.

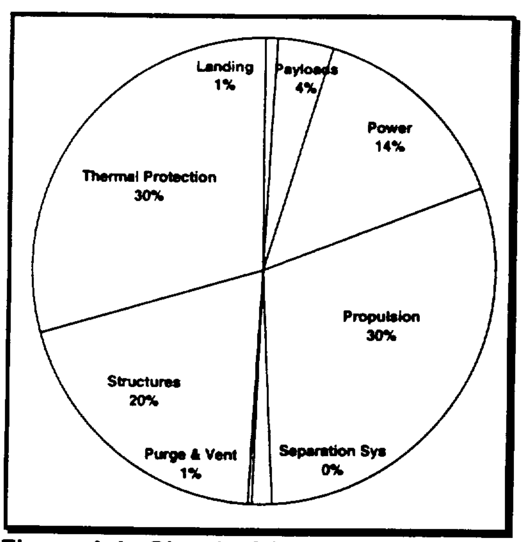

Figure 4-4 Shuttle GSE Per System

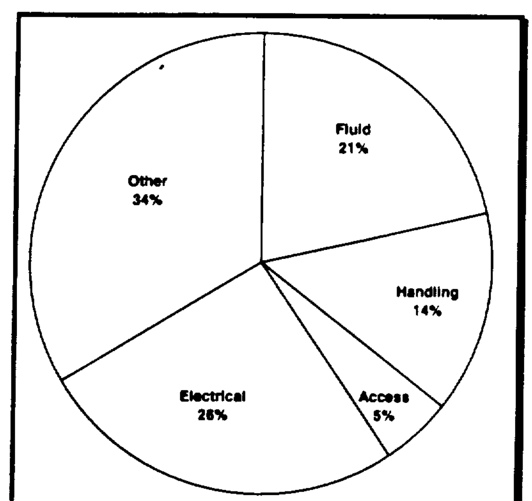

Figure 4-5 Shuttle GSE Per Category of Equipment

4.2.3 Operability Assessments

- Perhaps the most difficult information to gather (and the most subjective) were the operability assessments for both flight hardware and GSE. Both were rated in five areas: accessibility, reliability, maintainability, supportability, and availability.

Availability, maintainability, reliability, and supportability can be numerically expressed to understand exactly how well a system performs. But, development of numerical data for each orbiter subsystem was well beyond the scope of this research. Instead, subsystem experts were asked to provide subjective ratings for the flight hardware and GSE. The subjective ratings were "excellent," "good," "average," "fair," and "poor." The inputs data was converted to a numeric grades (from 1 to 5) to facilitate data evaluation. Table 4-3 is a summary of the flight hardware operability assessments and Table 4-4 is a summary of the GSE operability assessments.

Table 4-3 Flight Hardware Operability Assessment by Shuttle System

System	Accessibility	Availability	Maintainability	Reliability	Supportability
Comm & Track	2	N/A	3	3	2
Crew Systems	3.5	4	4	3.5	3.5
DMS	2	3	3	3.5	3
GN&C	2.8	3.8	3.5	3.3	3.5
Landing	1	4	2	5	2
Payloads	3.3	4	4	4	4
Power	2.3	4	2.3	3.7	3.7
Propulsion	2.6	3.5	2.8	3.3	3.5
Separation	3.5	4.5	4	4.5	4.5
Structures	2.6	3.2	3.4	3.6	3.4
Thermal Protection	3.6	3.6	2.3	3	2.6
Average	2.7	3.8	3.1	3.7	3.2

It was noted from several subsystem experts that the vehicle being processed today is quite different from the original. Design and operations personnel have worked hard over the years to make the system what it is today. Although designed 20 years ago, the vehicle has been upgraded and modified for enhanced mission support, success, and operability. Good ratings for accessibility, reliability, and maintenance are a reflection of this hard work. Modifications to hardware, changes in requirements and procedures, and additional tools and equipment undoubtedly have a significant effect on the timelines and current perceptions of operability.

It is not surprising that flight hardware operability has been rated low. Operability issues are common complaints within the launch vehicle community. Launch vehicles are large, complex, unique engineering marvels which are designed for high performance. Accessibility issues have often been overlooked, yielded to performance, or not corrected due to cost. Complex state-of-the-art hardware is often equated to high maintenance (average of 2324 scheduled maintenance tasks/1089 unscheduled maintenance tasks performed per flow) and expensive, long-lead time, short-supply spares destroys supportability ratings. The supportability issue is underscored by the cannibalization of orbiter main engines, OMS pods, electronics and other hardware to support the next scheduled mission. The high incidence of Problem Reports PRs (See Figure 4-3) indicates a less than optimum hardware availability and reliability (at least during ground processing). All of these factors accounting for low operability call for changes in new vehicle program planning and design philosophy. These changes documented in numerous launch site operations studies include:

- Standard off-the-shelf, proven hardware must be used to the greatest extent practical
- Plans must be based upon proven flight hardware and systems rather than using "clean sheet" approaches
- Concurrent engineering practices are essential in the design and build process, giving proper attention to operability issues
- Logistics support must be properly funded up-front and not sacrificed to fix budget problems

Operability of the GSE was not rated much better than the flight hardware operability. Common problems with the GSE include lack of parts for repairs, design and funding of GSE taking a distant second to flight hardware, high incidence of problem reports (See Figure 4-4), one-of-a-kind units that use unique parts, and antiquated equipment. The recommendations proposed above for enhancement of flight hardware operability also apply to the GSE.

Table 4-4 GSE Operability Assessment by Shuttle System

System	Accessibility	Availability	Maintainability	Reliability	Supportability
Comm & Track	4	N/A	2	2	1
Crew Systems	4	3	4	4	3.5
DMS	4	4	4	4	4
GN&C	3.8	3.6	3.4	3.5	3.8
Landing	4	4	2	5	2
Payloads	3.6	4.3	3.3	4.3	3.3
Power	3.3	3	3	2.7	3
Propulsion	3	3	3	3	3
Separation	4.5	3	3	3	3
Structures	3.2	3	3.4	2.8	3.2
Thermal Protection	4	4	3.5	3	4
Average	3.8	3.5	3.1	3.4	3.1

4.2.4 Conclusions

Considerable data was collected, analyzed, and assembled for development of the Launch Site Operation Design Data Book. Shuttle processing data and experience provided the basis for the data book as the Shuttle provides information for the full range of launch vehicle systems.

The Shuttle proved to be fertile ground for identification of launch site operations drivers and subsequent development of design goals for future launch vehicles. Table 4-5 provides a review of those systems/subsystems which are the greatest users of engineering headcount and GSE.

Numerous vehicle design goals have been identified for efficient turnaround operations reducing manpower, equipment, and facilities requirements. Overall, the goals focus upon the following seven principles:

- Eliminate hazardous and toxic materials including propellants and ordnance devices
- Eliminate multiple fuels and oxidizers on the same vehicle
- Furnish high reliability interfaces and flight and ground systems
- Eliminate complex and extensive assembly and test requirements
- Concurrent engineering practices must be used to ensure good accessibility, serviceability, and maintainability
- Provide robust flight hardware and systems that endure normal operating environments
- Reduce complexity of flight hardware and GSE using proven, off-the-shelf equipment

The format and methodology for data collection provides for easy update. Incorporation of data from other launch vehicles could be accomplished efficiently and would add to the value of the data book for future launch vehicles development and assessment. The data book is a valuable companion of the OIA artificial intelligence-based analysis tool. The data book can be used for updating existing templates within the tool library or development of new templates. Outputs of the OIA can also be validated or substantiated against the design data book system and subsystem information.

Timing for the data book completion is appropriate as NASA and aerospace contractors embark on development of reusable launch vehicle concepts (X-33 and X-34). Efficient ground operability of these new launch vehicles is intended to be a hallmark to reduce launch costs and decrease ground turnaround. Use of this data book along with sound concurrent engineering practices will help achieve cost and efficiency goals required for future launch vehicles.

Table 4-5 System /Subsystem Drivers of Manpower and Support Equipment Requirements

System/Subsystem	Engineering Headcount	Total GSE Units	Key Launch Site Drivers
Propulsion	*		
Main Engines, Propulsion	121	300	Lack of robustness; complex hardware; high maintenance; low reliability fluid interfaces; hydraulics; extensive test
Orbiter Maneuvering System/ Reaction Control System	*	536	Hazardous materials, toxic propellants; multiple propellants; high maintenance; hydraulics
SRB Mechanical	*	234	Extensive assembly, test, handling; hydraulic systems
Structures	151	350	Extensive assembly, test, handling; poor accessiblity, complex flight hardware
Thermal Protection System	95	790	Fragile materials; complex & unique processes; complexity;
Orbiter Electrical Power	*	440	High maintenance; extensive test; low maintainability; toxic propellants
Thermal Control: Environmental Control & Life Support	*	326	High maintenance, fragile materials
Launch Processing System	116	481	High maitenance; complex & unique processes; flight hardware complexity; extensive test

* Not a driver

5.0 TASK 3 - ASSESSMENT OF GROUND OPERATIONS IMPACTS

5.1 Task Overview

Under Task 3 of the Launch Site Processing and Facilities for Future Launch Vehicles study an investigation was conducted of the Kennedy Space Center (KSC) operational and facilities impacts created by the introduction of a new launch vehicle system. The following is an overview of the approach used to conduct the assessments, a general discussion of vehicles assessed, and a summary of the results. A complete description of each launch vehicle system configuration, top level processing scenarios, processing flows, lower level scenarios, timelines, and launch site impacts are contained in the separate "Operations Impacts Assessment Reports " document.

Task 3 included four sub-tasks, identify required assessments, acquire and format data, conduct analyses and determine launch site impacts, and perform mixed fleet analysis as illustrated in Figure 5 - 1.

Inputs	Work Flow	Products
Past and current vehicle design data	Task 3.1 Identify required assessments	Impact Assessments • Vehicle processing • Cargo integration requirements/timelines
Manifests (future launch vehicles and STS)	Task 3.2 Acquire and format data required to perform analysis	• Facility requirements • Equipment requirements
STS resource requirements		• Manpower requirements • Other resources
Current and projected infrastructure data	Task 3.3 Conduct and analyses and determine launch site impacts	Mixed fleet analysis (new vehicles with STS)
KSC prodcessing data by flight component	Task 3.4 Perform mixed fleet analysis	

Figure 5 - 1: Task 3 Contained Four Sub-tasks

5.1.1 Identification of Required Assessments

The NASA KSC research manager. identified eight launch vehicle systems comfigutations to be assessed. The launch vehicle systems considered were a combination of conceptual designs for expendable launch vehicles mated with manned and unmanned personnel and cargo transfer vehicles. These launch vehicle systems were developed by NASA as part of the Assured Access to Space Study effort. The launch vehicle systems identified are listed in Table 5 - 1 and a sample configuration of each launch vehicle system is shown in Figure 5 - 2.

Table 5 - 1: Launch Vehicle Systems Considered During Task 3 Impact Assessments

1	One and a half stage 50 klb launch vehicle with the HL-20 Personnel Launch System (PLS)
2.	One and a half stage with strap-on hybrid boosters 100 klb launch vehicle with the Winged Cargo Transport and Return Vehicle (WCTRV)
3.	Two stage 100 klb launch vehicle with the WCTRV
4.	One and a half stage 65 klb launch vehicle with the HL-42 PLS
5.	One and a half Stage 65 klb Launch Vehicle with Recoverable P/A modules and the HL-42 PLS
6.	Two engine, parallel burn 100 klb launch vehicle with the Piloted cargo Launch Vehicle (CLV-P)
7.	One and a half stage with strap-on hybrid boosters 100 klb launch vehicle with the CLV-P
8.	Two stage 100 klb launch vehicle with the CLV-P

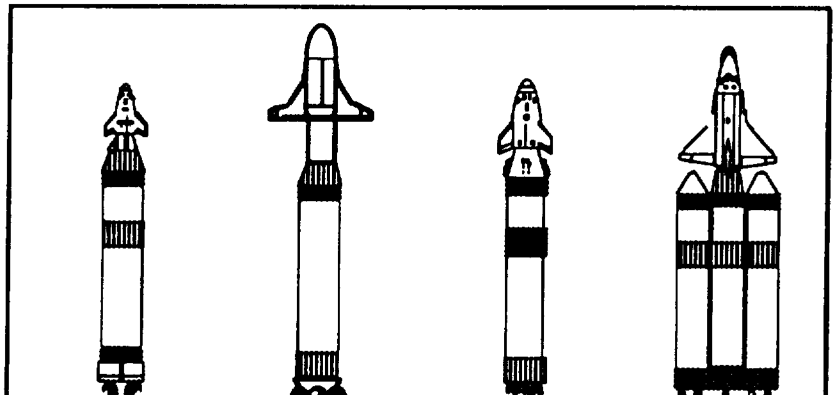

Figure 5 - 2: Sample of Launch Vehicle System Configurations Assessed

5.1.2 Data Acquistion and Formatting

The next step was to acquire and format data required to perform the analyses. The NASA KSC research manager provided launch vehicle and spacecraft data developed by several NASA centers during Assured Access to Space Study. The data provided for launch vehicles included information such as size, weight, propellant mass, and engine type. Table 5 - 2 lists the design data provided for the expendable one and a half stage 50 klb launch vehicle. Similar data was provided for the other launch vehicles. Design information for two of the spacecraft was much more detailed than that provided for the launch vehicles. Information provided for the HL-20 Personnel Launch System (PLS) is

Table 5 - 2: Expendable 1.5 Stage 50 klb Launch Vehicle Design Data

Core:	
Inert Mass	128.7 klb
Propellant Mass (Total)	1.83 Mlb
Propellant Type	LOX/LH2
Engine Type	STME
Number of Engines	1
Vacuum/Sea Level Thrust (ea.)	720/610 klb
Vacuum/Sea Level Isp	428.5/365 sec
Engine Exit Diameter	97 in
Length	175 ft
Diameter	27.6 ft
Reusability	None
Booster Module:	
Inert Mass	60.3 klb
Propellant Mass (Boost Phase)	1.44 Mlb
Propellant Type	LOX/LH2
Engine Type	STME
Number of Engines	3
Vacuum/Sea Level Thrust (ea.)	720/610 klb
Vacuum/Sea Level Isp	428.5/365 sec
Engine Exit Diameter	92 in
Length	N/A
Diameter	27.6 ft
Reusability	None
Notes:	
• Core/Booster Ignited on Pad with Holddown	
• GLOW	2.06 Mlb
• Total Weight @ Liftoff	1.19 Mlb

shown in Table 5 - 3. Similar information was provided for the Piloted cargo Launch Vehicle (CLV-P). Little more than the size and weight was provided for the Winged Cargo Transport and Return Vehicle (WCTRV) and the HL-42 PLS. For the purpose of the assessment it was assumed that the WCTRV was similar to the CLV-P, and the HL-42 was a scaled up version of the HL-20.

In addition to the physical characteristics provided for each element that constitutes a launch vehicle system, it was indicated that each element would arrive at KSC totally integrated (i.e., no assembly tasks were required at the launch site). Information regarding the various system and subsystem designs, and/or heritage, was provided or assumed in order to develop credible task durations for timelines.

One of the first and foremost concerns in assessing launch site impacts is the need for new or modified facilities. This is a major concern, because of the long lead time required to gain approval for facility construction (e.g., C of F budget process); the time and cost involved for environmental impact assessments; and the overall cost of construction and activation of these facilities. Modification of existing facilities is also a major concern,

Table 5 - 3: Personnel Launch System Design Data

Personnel Launch System (PLS) HL-20 Description	
1.	Lifting body concept designed by LaRC
2.	Designed for pilot, copilot and eight crew members (SSF crew change-out mission).
3.	Length 28.25 ft. Width 22.5 ft. wing tip to wing tip.
4.	Two primary components, crew compartment and heat shield.
5.	Secondary components consisted of two wings, eight large access panels and a center fin.
6.	Crew compartment was the primary structural element and was skin-stringer construction.
7.	The crew compartment consisted of a cylinder with a flat floor, a cockpit and close-out form the front and a conical section formed the aft end.
8.	Four frames extended from each side of side of the crew compartment to support the heat shield, subsystems and access panels.
9.	The crew compartment attached to the booster, via an adapter that provided an on-the-pad, or altitude, SRM escape system with 6 LES engines, at the aft end. An abort window existed from T + 64 to T + 403 seconds where the vehicle must abort to a water landing with parachutes.
10.	Entry at the launch pad was through a top hatch. Egress at SSF was through a hatch aft.
11.	The heat shield was suspended by links to the extension frames and crew compartment. It was removable to provide inspection access to the pressure vessel.
12.	The heat shield was constructed of graphite polyimide honeycomb with the tiles directly bonded to the polyimide. Directly bonding to polyimide with similar thermal expansion coefficient result in less maintenance than Shuttle/Orbiter. In addition to the tiles the TPS consisted of High-density Reusable Surface Insulation (HRSI) on the bottom of the heat shield and wings, Flexible Reusable Surface Insulation (FRSI) on the upper surfaces, and Advanced Carbon-Carbon (ACC) on the leading edges of the wing, control surfaces, nose (similar to the Shuttle/Orbiter nose), chines, and vehicle body flaps.
13.	All systems located outside the pressure vessel and were accessible through the access panels. The systems are; 2 OMS engines (port and strb), 4 RSC modules (fore and aft, port and strb), 2 battery packs (fore and aft), propellant tanks (port and strb), ECLSS (port and strb), tricycle landing gear (assumed to be pyro activated), parachute, and avionics bays (port and strb).

particularly if the modifications would interfere with ongoing launch program schedules. The type facility data required are illustrated in Table 5 - 4. Specific data on KSC facilities are presented in Appendix A.

Data for generic Shuttle (Orbiter, External Tank ET, and Solid Rocket Boosters) processing flows were extracted from KSC documentation by flight element , and used to develop timelines for the processing new launch vehicle system where elements, systems, or subsystems were similar. These data were entered into computer speadsheets to enableusers to make quick comparisons, and for input to the OIA.

Table 5 - 4: Physical Considerations of Launch Site Accommodations Required for Impact Assessment

Physical Considerations and Launch Site Accommodations
Size and weight of expendable and reusable vehicle components and operations as compared to availability and capability of:
a. Transporter(s) used to deliver vehicle components to launch site (e.g., barge, rail, truck or aircraft).
b. Equipment required to off-load vehicle components and transport to launch site processing facilities.
c. Launch site roadway clearances and load bearing capability
d. Type of facility required (hazardous or non-hazardous).
e. Facility size (length, width and height of door openings, airlock(s), work area and/or work stands)
f. Crane(s) hook height and load rating
d. Facility environment conditions (cleanliness, temperature, humidity, etc.)
e. Existing handling equipment (fork lifts, tow tractors, rotation devices, etc.)
f. Contamination control for hazardous or environmentally sensitive materials
g. Fixed and portable access stands
h. Test cells and footprints
i. Facility services (pressurized gases, liquids, electrical power, auxiliary lighting, etc.)
Engine configuration and thrust levels as compared to configuration and capability of:
a. Mobile Launch Platform (MLP)
b. Launch pad flame trench
c. Launch pad sound suppression system

5.1.3 Analyze and Determine Launch Site Impacts

Each assessment was conducted in the same manner, and a reusable Personnel Launch System (HL-20) launched on an expendable launch vehicle is used as an example in the following paragraphs to illustrate the assessment process. The launch vehicle system, Figure 5 - 3, consists of a HL- 20 atop a Core/Booster. The Core/Booster is a single engine core and a three engine booster that separates after launch. The first step in determining the impact of a new space vehicle on the launch site operations is to develop a top level processing scenario for the entire prelaunch process, from arrival (or retrieval)

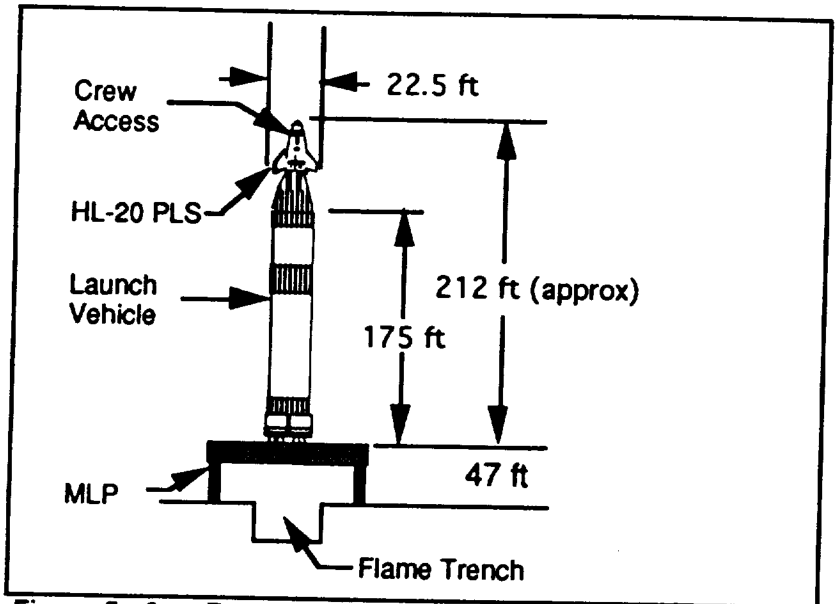

Figure 5 - 3: Reusable Personnel Launch System (HL-20) on an Expendable 1.5 Stage Launch Vehicle.

through launch, and in general terms define the facilities required during the processing flow for each of the new space vehicle elements. Figure 5 - 4 is the top level scenario developed

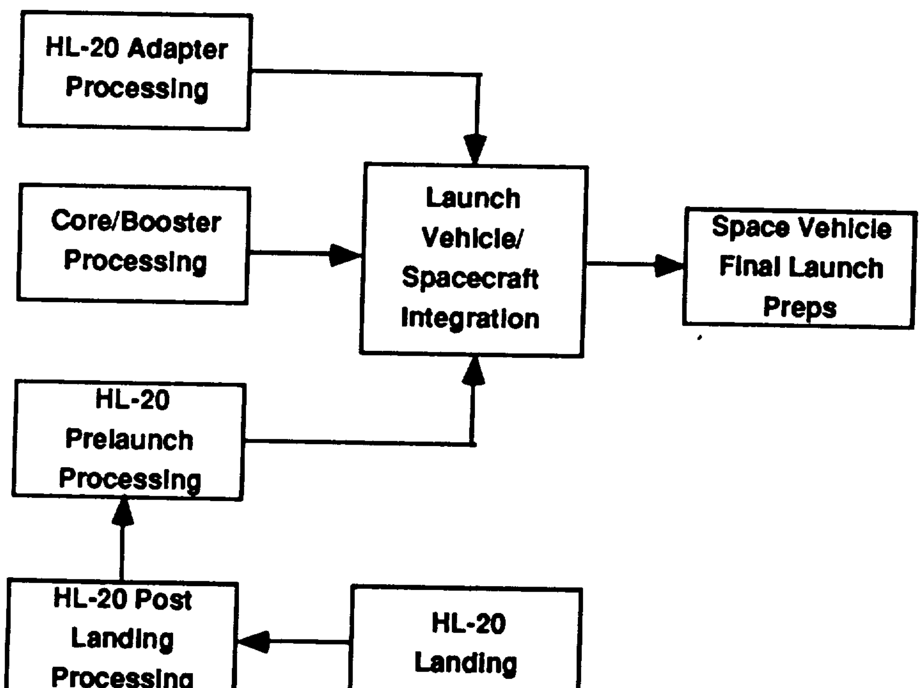

Figure 5 - 4: Top-Level Scenario for a Reusable Personnel Launch System (HL-20) Launched on an Expendable 1.5 Stage Launch Vehicle.

For the HL-20 launch vehicle system. The next step is to define the tasks performed on elements and systems, for each step contained in the top level processing scenario. Figure 5 - 5 shows an expansion of Core/Booster processing shown in the top- level scenario.

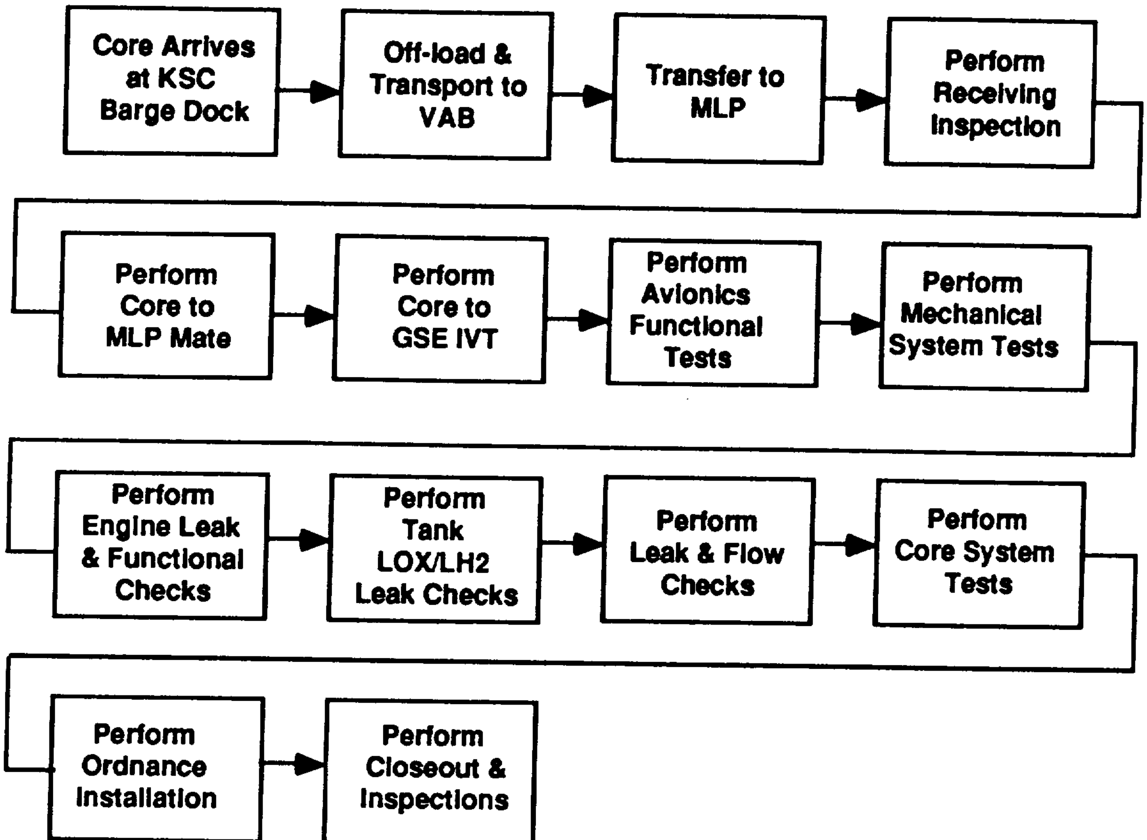

Figure 5 - 5: Lower-Level Core Processing Scenario

Following the development of the lower-level processing scenarios a comparison is made between the physical characteristics of each space vehicle element and the physical characteristics of existing facilities and/or support equipment to determine the ability of existing facilities and/or support equipment to accommodate the vehicle during all phases of processing.

This first assessment (vehicle physical characteristics versus facility capabilities) is initially accomplished assuming that all facilities are available on a non-interference basis with ongoing launch operations. In the example presented above, the space vehicle could be processed in existing facilities with some modifications.

If the integration of the tanks, core engine, and booster assembly were accomplished at Marshall Space Flight Center (MSFC) the vehicle could be shipped to Kennedy Space Center (KSC) using the barge normally use to transport the Shuttle External Tanks (ET) to KSC. However, some modifications to the barge may be required to provide environmental protection for engine and booster components. At KSC, the Shuttle ET transporter would have to be modified to transport this element from barge dock to the

Vehicle Assembly Building (VAB), because the integrated Core/Booster is longer and heavier than the Shuttle ET. One of the VAB high bay areas would require modifications to provided access to the Core/Booster and HL-20 during mating and test operations. At least one of the Orbiter Processing Facility (OPF) bays would required modifications to accommodate the smaller HL-20. One of the Mobile Launch Platforms (MLP) would require a modification to close two openings, which allow hot exhaust from the Shuttle Solid Rocket Boosters (SRB) to escape into the flame trench, , and the flame trench at one pad may also require modifications. Modifications would be required to provide crew access at the pad. The Orbiter Access Arm used for Shuttle is not at the proper level to satisfy this requirement for the stacked 1.5 Stage, 50 klb, HL-20 System. Crew access for the HL-20 is through a top hatch that would be at the 247 foot level when on the MLP at the pad, and the Orbiter Access Arm is at the 147 foot level (See Figure 5 - 3).

Once it has been determined that new or modified facilities are, or are not, required, time estimates or "timelines" are developed for each processing task. These timelines are derived from standard processing timelines for existing vehicle elements and systems that are similar to the elements and systems used on the new vehicle. A timeline for the example space vehicle is illustrated in Figure 5 - 6. Impacts relating to facility utilization,

ID	Tasks	Work Days
1	HL-20 Landing at SLF	0
2	HL-20 Postlanding Processing	47
3	Safe & Tow to Processing Facility	0.75
4	Postlanding Inspections	20
5	Remove OMS & RCS	8
6	Thermal Protection System Refurbishment	20
7	Post-Flight Functional Test	6
8	Scheduled Maintenance & Repairs	30
9	Refurbish Crew Systems	8
10	Battery Servicing	4
11	HL-20 Prelaunch Processing	34.5
12	OMS & RCS Reinstallation	8
13	Fluids & Gases Servicing	6
14	Flight Readiness Test	4
15	Crew Equipment Installations	4
16	Ordnance Installation & Test	6
17	Closeouts	4
18	Weight & CG	1
19	Install on Transporter	1
20	Transport to VAB	0.5
21	Core/Booster Processing	134
22	Core Arrival at Barge Dock	0
23	Core Offload & Transport to VAB	4

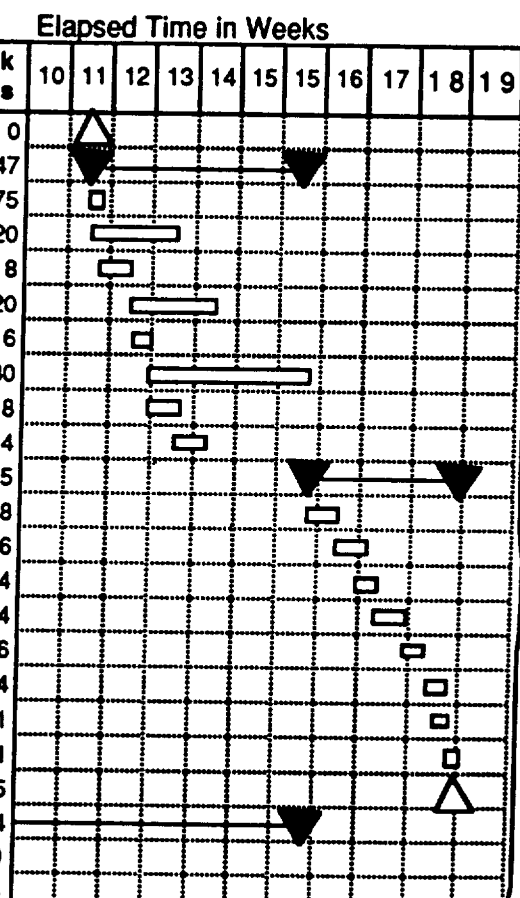

Figure 5 - 6: Illustration of a Processing Timeline

can be identified by comparing the timelines and estimated launch rates for the new vehicle with schedules and manifests for Shuttle.

5.1.4 Perform Mixed Fleet Analysis

Timelines developed during the assessments were based on mature operations, in that first time flows for new vehicle systems, and learning curves were not considered. A summary of the processing times for the example launch vehicle system, Table 5 - 5, shows a total elapsed time for turnaround to be 113 calendar days. This compares to the average post-Challenger STS turnaround time of 184 calendar days. Multi-flow conflicts for the use of the VAB would be encountered between Shuttle processing and any new launch vehicle system. For example, the 34 days required to stack the Shuttle Solid Rocket Booster (SRB) segments are "lock-out" days in that no other activities are permitted at that time. If these multi-flow conflicts can not be resolved through schedule adjustments additional facilities, such as an SRB stacking facility, and/or other facility modifications may be in order.

Table 5 - 5: Summary of Processing Times for the Reusable Personnel Launch System (HL-20) on an Expendable 1.5 Stage Launch Vehicle.

Task	Shifts	Time In Calendar Days*	Turnaround Time In Calendar Days	Facility
HL-20 Post Landing Processing**	47	32.9	0.0	OPF
HL-20 Prelaunch Processing**	34.5	24.2	0.0	OPF
Core/Booster Processing	134	93.8	93.8	VAB
HL-20 Adapter Processing**	30	21.0	0.0	VAB
Launch Vehicle/Spacecraft Integration**	81	27.0	0.0	VAB
Final Launch Preps	57	19.0	19.0	Pad
Totals	383.5	217.9	112.8	

* Based on 2 shifts/ day, 5 days/week for element stand-alone operations and 3 shifts/day 7 days/week for integrated operations.

** Performed in parallel with Core/Booster Processing.

The nature of facility modifications and the time required to complete the modifications may also have an impact on ongoing operations. For example, Shuttle launch rates would be affected during VAB bay modifications to accommodate the Launch Vehicle/Spacecraft integrated operations.

5.2 *Results*

The following summarizes the Task 3 assessment results in terms of new or modified launch site facilities and equipment required, new launch vehicle system turnaround time estimates, and schedule conflicts arising from mixed fleet operations.

5.2.1 Facility Impacts

Launch site facility modifications for the one and a half stage 50 klb launch vehicle with the HL-20 Personnel Launch System previously in described in Paragraph 5.1.3 are typical of the modifications required for most of the launch vehicle systems assessed..

It was assumed that in all cases where the core and booster constituted a single integrated element that integration would be accomplished at some other facility prior to being shipped to KSC. It was also assumed that these integrated core/boosters would be transported to KSC on the Shuttle ET barge. For these launch vehicle systems one or more Shuttle ET transporters would have to be modified and/or new transporters provided to transport these elements from barge dock to the VAB, because integrated core/booster elements were longer and heavier than the Shuttle ET. For these launch vehicle systems, such as the one and a half stage with hybrids 100 klb launch vehicle with the WCTRV, where the core and the booster(s) were separate elements new transporters would be required for the boosters and/or the core element.

VAB high bay areas would require modifications to provided access to the launch vehicle and spacecraft during mating and test operations. At least one of the OPF bays would required modifications to accommodate the smaller spacecraft. One of the MLP would modification, and the pad flame trenches would require rework for core engines configurations.

For the 1.5 Stage with Recoverable Propulsion/Avionic (P/A) 65k Launch Vehicle with HL-42 and 2 Engine Parallel Burn Cluster with CLV-P the Rotating Service Structure (RSS) provided for payload access and access to Orbiter systems, could not be used. The top of the RSS is at the 167 foot level at the pad. With the HL-42 configuration the adapter would start at the 213 foot level, the adapter was 13 feet long and the HL-42 was 42 feet, the top of the stack would be at the 268 foot level. The top of the CLV-P stack would be at the 277 foot level, and if access to the top of the stack is required at the pad the top deck of the Fixed Service Structure (FSS) at the 247 foot level, may have to be raised. New access arms and escape systems would be required for the crew. The RSS would have to modified to provide access capability for cargo loading operations.

It is assumed that the SRB recovery ships provide adequate overall capabilities for retrieval of the P/A modules. Re-outfitting of the ships will probably be required for the P/A recovery missions. Recovery and refurbishment of the LOX/LH2 engines (P/A modules for the 1.5 stage configuration) from an ocean landing would be a new and exciting experience for KSC.

5.2.2 Turnaround Time for Launch Vehicle Systems

One of the goals the Assured Access to Space effort was to investigate launch vehicle systems designs and operational concepts that would allow launch operations to approach typical aircraft operations and turnaround times. Many gross assumptions were made in developing the timelines for turnaround estimates for the launch vehicle systems assessed. This was due to the lack of specific design data related to reliability, maintainability, and supportability characteristics that are normally used to determine aircraft turnaround time estimates. The estimates developed in Task 3 were based on generic flows and timelines for the Shuttle. Shuttle generic flows and timelines are "success oriented" and do not include allowances for unplanned work.

Table 5 - 5, in Paragraph 5.1.4, is a summary of processing times for the reusable Personnel Launch System (HL-20) on an expendable 1.5 stage launch vehicle. Tables 5 - 6 provides summaries of the turnaround times for the other launch vehicle systems assessed. The maximum turnaround time was 112.8 calendar days and the minimum was 77.8 calendar days. These estimates indicate the launch vehicle systems assessed would not provide a significant improvement over the Shuttle in regard to turnaround time. This is not surprising, because the estimates were based on Shuttle element processing.

5.2.3 Schedule Conflicts for Mixed Fleet

Modifications to the VAB would disrupt Shuttle processing and an annual flight rate of eight flights per year could not be maintained during the duration of the modifications. Conversely, modifications to the VAB would disrupted by Shuttle processing. Launch rates for any new launch vehicle system would also be effected by on-going Shuttle operations. This would be particularly true in the VAB where hazardous SRB stacking "lock-out" any other activity. The average SRB stacking operation duration is 35.4 calendar days, and shortest time, as of May 18, 1993, was 17 calendar days. This was accomplished on mission STS-54 in the October/November 1992 time frame. The generic stacking flow is 19 calendar days based on a 3 shift per day 5 days per week work schedule. Assuming the generic schedule could be met consistently and a flight rate of eight Shuttle flights per year the VAB would be unavailable on average for 152 calendar days. A new SRB stacking facility would alleviate the situation , however it would seem that a new vehicle integration facility, designed specifically for the new launch vehicle system would be more appropriate.

Table 5 - 6: Turnaround Time Estimates

Task	Shifts	Time in Calendar Days*	Turnaround Time in Calendar Days	Facility
1.5 Stage w/strap-ons 100 klb Launch Vehicle w/WCTRV				
WCTRV Post Landing Processing**	55.5	38.9	0.0	OPF
WCTRV Prelaunch Processing**	34.5	24.2	0.0	OPF
Core/Booster Processing	84	58.8	58.8	VAB
Strap-Ons Processing Left & Right**	66	46.2	0.0	VAB
WCTRV Adapter Processing**	30	21.0	0.0	VAB
Launch Vehicle/Spacecraft Integration**	47	15.7	0.0	VAB
Final Launch Preps	57	19.0	19.0	Pad
Totals	374	223.7	77.8	
2 Stage100 klb launch vehicle w/WCTRV				
WCTRV Post Landing Processing**	55.5	38.9	0.0	OPF
WCTRV Prelaunch Processing**	34.5	24.2	0.0	OPF
Core/Booster Processing	82	57.4	57.4	VAB
Strap-Ons Processing Left & Right**	45	31.5	0.0	VAB
WCTRV Adapter Processing**	30	21.0	0.0	VAB
Launch Vehicle/Spacecraft Integration**	47	15.7	0.0	VAB
Final Launch Preps	57	19.0	19.0	Pad
Totals	351	207.6	76.4	
1.5 Stage 65 klb launch vehicle w/HL-42				
HL-42 Post Landing Processing**	51.5	36.1	0.0	OPF
HL-42 Prelaunch Processing**	38.5	27.0	0.0	OPF
Core/Booster Processing	134	93.8	93.8	VAB
HL-42 Adapter Processing**	30	21.0	0.0	VAB
Launch Vehicle/Spacecraft Integration**	57	19.0	0.0	VAB
Final Launch Preps	57	19.0	19.0	Pad
Totals	368	215.8	112.8	
1.5 Stage 65 klb w/recoverable P/S launch vehicle w/HL-42				
HL-42 Post Landing Processing**	51.5	36.1	0.0	OPF
HL-42 Prelaunch Processing**	38.5	27.0	0.0	OPF
Core/Booster Processing	96	67.2	67.2	VAB
Strap-Ons Processing Left & Right**	66	46.2	0.0	VAB
HL-42 Adapter Processing**	30	21.0	0.0	VAB
Launch Vehicle/Spacecraft Integration**	45	15.0	0.0	VAB
Final Launch Preps	57	19.0	19.0	Pad
P/A Module Post-Launch Operations**	15.5	5.2	0.0	Hanger AF
Totals	399.5	236.6	86.2	
2 Engine parallel burn 100 klb w/CLV-P				
CLV-P Post Landing Processing***	51.5	36.1	10.0	OPF
CLV-P Prelaunch Processing**	44.5	31.2	0.0	OPF
Core Processing***	54	37.8	7.0	VAB
Booster Processing Left & Right	64	44.8	44.8	VAB
CLV-P Adapter Processing	30	21.0	0.0	VAB
Launch Vehicle/Spacecraft Integration	46.5	15.5	0.0	VAB
Final Launch Preps	57	19.0	19.0	Pad
Totals	347.5	205.3	80.8	

Table 5 - 6: Turnaround Time Estimates (Continued)

Task	Shifts	Time in Calendar Days*	Turnaround Time in Calendar Days	Facility
1.5 Stage w/strap-ons 100 klb launch vehicle w/CLV-P				
CLV-P Post Landing Processing**	55.5	27.8	0.0	OPF
CLV-P Prelaunch Processing**	34.5	24.2	0.0	OPF
Core/Booster Processing	84	58.8	58.8	VAB
Strap-Ons Processing Left & Right**	66	46.2	0.0	VAB
CLV-P Adapter Processing**	30	21.0	0.0	VAB
Launch Vehicle/Spacecraft Integration****	47	15.7	5.0	VAB
Final Launch Preps	57	19.0	19.0	Pad
Totals	374	212.6	82.8	
2 Stage100 klb w/CLV-P				
CLV-P Post Landing Processing***	55.5	27.8	7.0	OPF
CLV-P Prelaunch Processing**	34.5	24.2	0.0	OPF
Core/Booster Processing	84	58.8	58.8	VAB
Strap-Ons Processing Left & Right**	64	44.8	0.0	VAB
CLV-P Adapter Processing**	30	21.0	0.0	VAB
Launch Vehicle/Spacecraft Integration****	47	15.7	5.0	VAB
Final Launch Preps	57	19.0	19.0	Pad
Totals	372	211.2	89.8	

* Based on 2 shifts/ day, 5 days/week for element stand-alone operations and 3 shifts/day 7 days/week for integrated operations.

** Performed in parallel with Core/Booster Processing or off line.

*** CLV-P Post Landing Processing starts 10 days before Core Processing and Core Processing starts 7 days before Booster Processing.

**** Extends 5 days beyond Core/Booster Processing.

6. TASK 4 - DEVELOPMENT OF METHODOLOGIES TO IDENTIFY PROMISING TECHNOLOGIES

6.1 Task Overview

Numerous technologies, advanced systems, and process improvements are needed to improve current capabilities for processing launch vehicles and related payloads. Use of advanced systems and technologies can reduce cost and increase the efficiency of ground processing operations. However, many technologies and techniques require significant lead times and expenditures in order to be available for operational use. The overall objective of Task is to provide tools and data for identifying the critical technologies needed to improve ground processing operations. There were two specific objectives to be met in Task 4. One is the identification of those technologies which, if implemented, will play a significant role in improving processing and reducing the cost of future vehicle processing. That is, what process enhancements can be made if certain technologies are implemented. Note, this contract does not involve determining the current state-of-the-art of the needed technologies.

The second objective of this contract is to provide designs, models, and suggested modifications to the OIA that will allow technology needs to be modeled along with typical processing data. This includes the ability to specify a given technology or enhancement technique for a given task. It also includes the ability to store data pertaining to technology information. This would include the cost of developing the technology for field use, current-state-of the-art, listing of experts etc. In addition to including this modeling the data the design should include new reports which make use of this data, such as technology listings showing when each is needed for a given program. There are a number of other reports which must be included as well. Note, these are not actual changes or requirements of the OIA tool. They are simply guidelines and plans which could be implemented in a future modification of the tool.

The specific deliverables of Task 4 include the following:

1. Listing of critical technologies needed (mid-term and final report)
2. A methodology and design for modeling technology information within the OIA

6.2 Identification of Promising Technologies

6.2.1 Background

The technologies identified here were obtained from extensive interviews with various shuttle processing engineers, and from various technology studies carried out by teams with extensive processing experience. The Launch Vehicle NRA team, consists of individuals with extensive processing experience across numerous spacecraft programs.

This experience was used to perform relevant interviews with various processing personnel, and carefully select only relevant information from other studies. Because the STS program is an ongoing program with an extensive history of processing knowledge it was used as a primary driver to identify new methods and technologies to process future vehicles efficiently. STS processing information was obtained by directly interviewing various shuttle processing teams. As shown in Section 5 the data obtained from these interviews has been used in the Launch Site Operations Design Data Book and to identify technologies to enhance future vehicle processing.

Two other primary sources of data were used here. One is the Space Station Ground Processing study that was a KSC based effort to identify improved methods and technologies required to reduce the cost of processing the station elements. This study was accomplished in a manner very similar to the STS processing team interviews. Numerous experts in payload processing, familiar with current plans for Space Station were interviewed to determine problem areas and propose enhancements. The final source of data was NASA's Reusable Launch Vehicle program. Large center wide teams have been established to address issues for this program and define the drastic changes and requirements necessary to build a reusable launch vehicle that is an order of magnitude less costly to fly. The data obtained here comes from the combined NASA/Industry Operations Technology Synergy Team. The findings of this team, chartered to review and prioritize the Access to Space, Option 3 Technology Requirements, are presented in a package of 4 documents delivered in November 1994. The Access to Space Study identified numerous options for future launch vehicles and requirements and was the precursor to the RLV program. The complete list of documents from which technology needs have been obtained are listed below:

1. Interview data obtained from discussions with STS KSC processing subsystem experts. Data taken from the STS Operations Database developed under Task 2 of the Launch Site Processing and Facilities for Future Launch Vehicles Study.
2. "Launch Site Operations Design Data Book,", Interim Report, Launch Site Processing and Facilities for Future Launch Vehicles, NASA Contract #NAS10-11999, June 1994.
3. "Advanced Technology for Enhanced Space Station Ground Processing Study," Phase I Final Report, Payload Ground Operations Contract #NAS10-11400, Work Order deliverable, NASA-KSC, November 1993.
4. "Access to Space Study," NASA Office of Space Systems Development, January 1994. (Summary Report, Advanced Technology Team Final Report Volume I - Summary, and Volume IV - Operations Plan)
5. RLV Operations Technology Plan, RLV Operations Synergy Team, October, 1994.
6. "Operations Concept Vision and Operability Criteria Document", RLV Operations Synergy Team, November 1994.

7. "Technology Priorities Identification," RLV Operations Synergy Team, October, 1994.

8. "Critical Technologies for Improved Processing," Interim Report, Launch Site Processing and Facilities for Future Launch Vehicles, Contract #NAS10-11999, August, 1994.

As mentioned above the LVNRA contract called for a mid-term and final report listing technology needs for future vehicle processing. Thus, the data presented here is an extension of the technology requirements already identified in the mid-term report.

6.2.2 Technology Listing

Based on the approach described above, and using the listed sources for information, a total of 43 technologies or process enhancements have been identified to date. The technologies identified are grouped into a set of task types and general areas or categories for convenience. The primary focus of this assessment is enhancement for ground operations. Thus, most of the technologies are based on improvements and new technologies for current ground operations and ground equipment. However, there are certain technologies which can be used to enhance or modify the spacecraft itself which results in reduced maintenance and operations. The technology category for this case is referred to as "Flight". For instance the use of advanced propulsion systems which do not require separating boosters to be recovered obviously reduces ground operations costs. The technology areas used in this report are listed below:

1. Test and checkout
2. Transportation and handling
3. Installation, assembly, and disassembly
4. Human ingress and egress
5. Inspection
6. Servicing and deservicing
7. Generic enhancements
8. Flight Equipment

Table 1 provides a listing of the technologies categorized by specific task type. Also shown are the sources from which each was identified. Table 2 provides a listing of technologies, and the sources for those technologies which are generic and applicable to more than one type of processing task. A brief description of each technology and its source is provided in Appendix B.

TABLE 1. Identified Technologies To Enhance Vehicle Processing - Organized By Task Type

	Task Type	Technology/Application	Source	Comments/Example
1	Flight Equipment	Electro-Mechanical Actuators for Flight Control	STS Interview Database	
2	Flight Equipment	Modular Propulsion System	RLV Operations Synergy Team	
3	Inspection	Access Platform Proximity Sensors	STS Interview Database	
4	Inspection	Articulated Camera/Scope Carriers	Space Station Ground Processing Study and STS Interview Database	Automated engine compartment inspection
5	Inspection	Automated Leak Detection and Location	RLV Operations Synergy Team	
6	Inspection	Automated Material Inspection	STS Interview Database	
7	Inspection	Thermal Imaging	RLV Operations Synergy Team	
8	Installation and Assembly	Self Adjusting Latches	STS Interview Database	
9	Installation and Assembly	Automated Tile/Skin Handling	STS Interview Database	
	Servicing & Deservicing	Advanced Foams and Material Coatings	STS Interview Database	
11	Servicing & Deservicing	Automated Umbilical Connectors	STS Interview Database and RLV Operations Synergy Team	
12	Servicing & Deservicing	Improved Quick-Disconnects	RLV Operations Synergy Team	
13	Servicing & Deservicing	Predictive Maintenance Techniques	RLV Operations Synergy Team	
14	Test & Checkout	Automated Battery Checkout	STS Interview Database	Short processing/charging time
15	Test & Checkout	In-Situ Measurement Systems	STS Interview Database and Space Station Ground Processing Study	In-line pressure guage
16	Test & Checkout	Intelligent Sensors	STS Interview Database	On-board electronics for signal conditioning, AD conversion, and data interface
17	Test & Checkout	Wireless Signal/Data Communication	Space Station Ground Processing Study	
18	Transportation & Handling	Automated Payload/Vehicle Handling and Mating Systems	STS Interview Database	
[illegible]	Transportation & Handling	Electrical Actuators for GSE	STS Interview Database	Automated SS Rack insertion device
20	Transportation & Handling	Standardized Auto-Aligning Payload Interfaces	RLV Operations Synergy Team	

6.3 Potential Spin-off Opportunities

There is currently tremendous pressure on government agencies and their contractors who perform research and development work to transfer technology into commercial industry in order to stimulate job growth. In support of this effort, the technologies for processing enhancement, identified here, have also been considered as potential "spin-off" opportunities. A team of 5 personnel with extensive payload and spacecraft processing experience was used to identify potential "spin-off" opportunities. It should be noted that a number of needed processing technologies actually represent more of a "spin-on" opportunity. That is, there are areas of processing that could benefit from commercially available equipment. The "spin-off" opportunities that were identified in a brief effort are depicted below.

TABLE 2. Identified Technologies To Enhance Vehicle Processing - Generic Tasks

	Task Type	Technology/Application	Source	Comments/Example
21	Generic Technologies	CAD Data Conversion	Space Station Ground Processing Study	
22	Generic Technologies	CAD/CAM Part Production	Space Station Ground Processing Study	
23	Generic Technologies	Computer Graphic Visualization	Space Station Ground Processing Study	Payload access study
24	Generic Technologies	Computer-Aided Logistics	Space Station Ground Processing Study	Payload/GSE graphic model
25	Generic Technologies	Computer-Aided SW Engineering	Space Station Ground Processing Study	
26	Generic Technologies	Computer-Based Training	Space Station Ground Processing Study	
27	Generic Technologies	Data Acquisition	Space Station Ground Processing Study	
28	Generic Technologies	Data Compression	Space Station Ground Processing Study	
29	Generic Technologies	Emissivity/Reflectivity Sensors	Space Station Ground Processing Study	Radiator measurement
	Generic Technologies	Expert Systems	Space Station Ground Processing Study	Automated ECLSS test
31	Generic Technologies	Fiber-optic Data Communication	STS Interview Database	
32	Generic Technologies	Fluid Purity Systems	Space Station Ground Processing Study	
33	Generic Technologies	High-Density Storage	Space Station Ground Processing Study	
34	Generic Technologies	High-Level Programming Environments	Space Station Ground Processing Study	
35	Generic Technologies	Laser Ranging and Measurement	Space Station Ground Processing Study	Alignment of payload trunions to hooks
36	Generic Technologies	Machine Vision and Automated Inspection	Space Station Ground Processing Study	Inspect tile defects
37	Generic Technologies	Model-Based Reasoning System	Space Station Ground Processing Study	LOX loading system
38	Generic Technologies	Noncontact Digitization	Space Station Ground Processing Study	Tile cavity measurement
39	Generic Technologies	Object-Oriented Programming	Space Station Ground Processing Study	
40	Generic Technologies	Process Planning	Space Station Ground Processing Study	
41	Generic Technologies	Robotic Manipulators	Space Station Ground Processing Study	HEPA filter inspection
42	Generic Technologies	Virtual Instrumentation	Space Station Ground Processing Study	
43	Generic Technologies	Work Control Systems	Space Station Ground Processing Study	

6.3.1 Automated Battery Checkout/Advanced Battery Systems

One obvious area of improvement required both in the spacecraft and industrial areas is the development of improved batteries. If a longer lasting, more powerful battery could be developed it would have an extensive potential for profit. The following list illustrates a few of the typical, large markets available if advanced batteries can be developed:

- Various consumer devices and cellular phones
- Military field devices
- Electrical vehicles
- Forklift and manufacturing vehicles

6.3.2 Intelligent Sensors and Control

Spacecraft, payloads, manufacturing plants, modern automobiles all represent systems that require enormous numbers of sensor devices to operate. Often there are problems in obtaining sensor data. In many cases it cannot be determined if the bad data is really present, the sensor itself is malfunctioning, or there is a related wiring problem somewhere in the system. This is true with the majority of sensors in place today, which typically generate analog signals. An intelligent sensor would be capable of sensing the data, conditioning the analog signal, and converting it to digital form for communication. With today's electronics these devices can be extremely small, low power devices. Their primary advantage is data can be sent on small cable bundles or even a single line as opposed to thousands of analog wires. Because these sensors can be continuously monitored and are digital data devices, any anomaly in sensing can be realized very quickly. This technology may however represent more of a "spin-on" technology since these devices are now becoming available in commercial products such as automobiles.

6.3.3 Inspection of Pressure Vessels and Piping

Extensive techniques for non-destructive evaluation (NDE) and video inspection of metal structures, piping, aircraft components etc. have been developed within aerospace programs. These techniques could be commercialized in any area where inspection remains a very costly and time consuming task. For instance the inspection of underground gasoline tanks which is required at regular intervals.

6.3.4 Expert Systems

Expert systems, which in essence capture the knowledge of a particular human decision making process, have yet to make a large impact in the commercial business environment. However, their use is much more prevalent in military and space systems. Although there are commercial applications making use of expert systems, it is still extremely difficult to obtain knowledge, verify the performance and validity of an expert system, and maintain a knowledge based system. If this process becomes easier due to the use of tools developed by or for government agencies then a much larger market for this technology would develop. Typical markets that could evolve include intelligent building controls, utility plant control and manufacturing operations.

6.3.5 Non-Contact Digitization

There are a number of applications in spacecraft processing that require the detailed measurement of three-dimensional objects or volumetric spaces. For instance, the replacement of space shuttle tiles involves the automated measurement of a unique, cavity for a specific tile. This measurement, which in essence forms a three-dimensional model for the tile, is used to fabricate a custom fitting tile. Other uses of this technology include identifying arbitrary objects in a workspace (dimensions and shape, location, orientation) so mobile devices and manipulators can be automatically guided through the area without colliding with anything. Various methods are now evolving to implement this capability. These include stereo vision s and laser scanning. The ability to measure volumetric areas and components obviously has extensive commercial application. A brief list includes:

- Dentures and dental devices
- Bone duplication
- Verification of original three-dimensional art
- Archeological measurement
- Criminal investigation

- Plastic surgery.

6.3.6 Leak Detection

Various gas monitoring technologies are used in spacecraft and associated facilities. Unfortunately these devices remain expensive and difficult to miniaturize. Thus it is difficult to place sensors throughout a vehicle for monitoring. However, if the technology can be developed to deploy various gas type sensors in large quantities there would be extensive commercial opportunities. These opportunities include chemical plant monitoring, and vehicle carbon-monoxide monitoring.

6.4 Methodology to Identify Needed Technologies

Numerous working groups, managers, and technology development programs require high-level information about various technologies. For instance, what technologies have the greatest impact on future programs? Are there technologies which are essential for a given program? If a given technology is not available for field/flight use what is the added cost to the program? These questions can, in some cases, be answered with a process model by handling technology information as a resource. That is, for a given task or subtask a necessary technology is shown as required just like GSE, manpower etc. The OIA system developed to date is a general modeling tool. Normally, a specific base template of objects is used for new projects. The models shown so far focus on vehicle components, facilities, equipment and processing tasks. However, any object, sets of sub-objects, and arbitrary attributes can be modeled in the current OIA. Thus, basic technology information could be defined in the current OIA. The ability to choose which technologies are required for a given task, and reporting about technology information however, is not part of the current system. The modeling technique presented here is simply a conceptual framework for enhancing the OIA to handle technology modeling at a future date. Because the OIA tool has been designed in a general manner, these enhancements would, most likely, be easy to implement.

6.4.1 How Can Technologies be Modeled?

A typical user, attempting to assess technology needs for a given program, will normally start with various technology scenarios or options. That is, one case may be the use of current systems only and no new technology based operations, and another case may be the maximum use of known advanced technologies for all operations. Thus, for any given set of available technologies or scenarios a set of reports could be generated and compared. The end-use of any technology information in a model is these reports which attempt to answer some of the questions just described above. The specific reports that could be developed with the method described here include:

- Required technology development start dates
- Required technology development cost
- Total operations cost per technology scenario
- Technology Readiness Assessment

- List of required technologies, their current readiness level, and the number of years to develop

To generate these reports the technology information must be modeled within the OIA. As mentioned above, the OIA tool represents generic objects within the Vehicle Definition Assistant. A given technology can be defined just like any other resource. The highest level object required would be named "Technologies/Enhancements". This is the object that would include all specific technologies or, or specific process methods, devices etc. that may be used during any task. In order to represent, for example, the technologies identified in Section 6.2, two more levels of objects would be required. One would represent the area or technology category, and then within each category specific technologies could be defined. The concept of technology objects is illustrated in Figure 6-1.

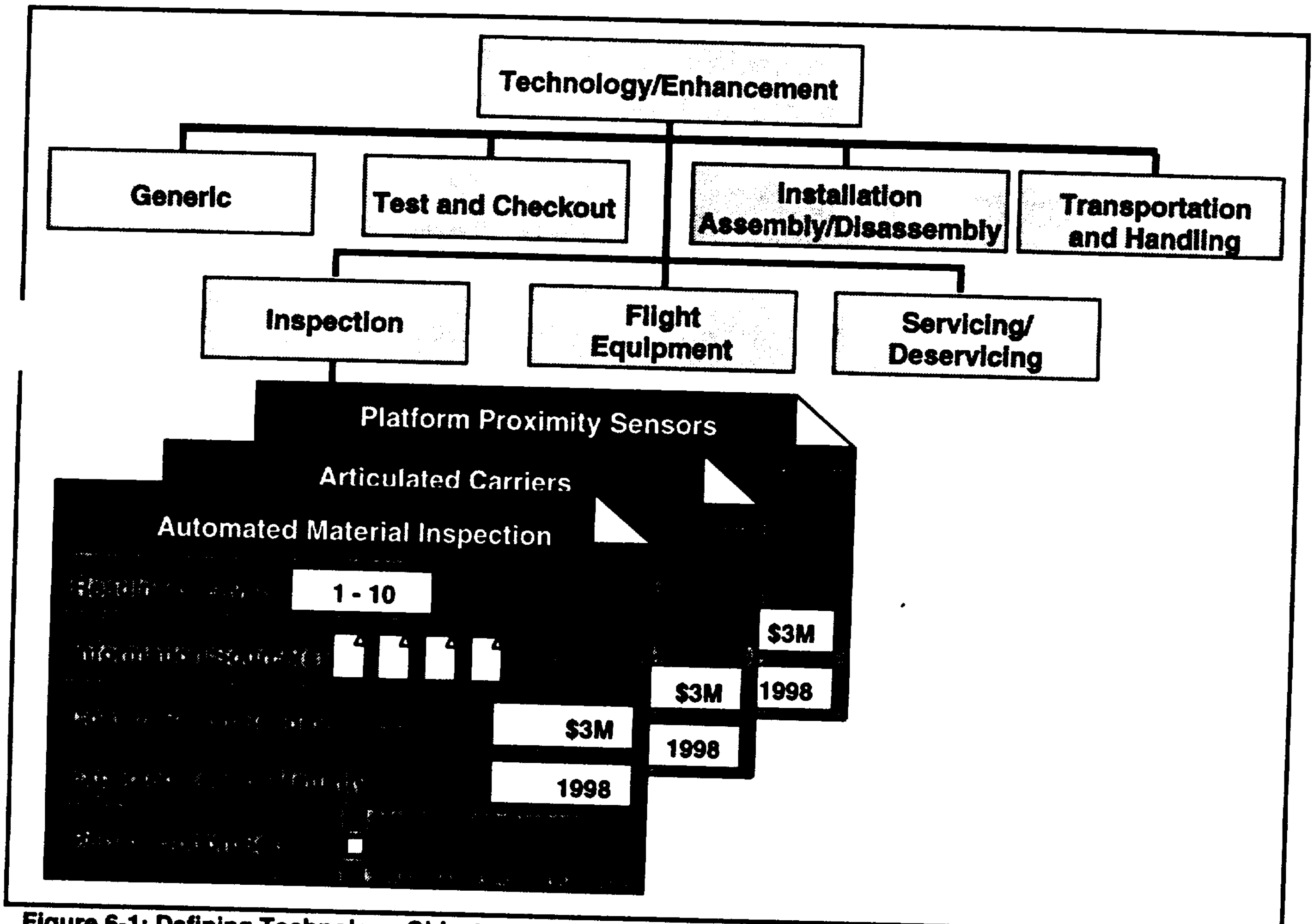

Figure 6-1: Defining Technology Objects

Attributes, that is the specific information known about each technology, must be defined as well. The overall object "Technology/Enhancement", must also have one set of attributes that the defines the available sets of technology scenarios. Each set of

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technology options will have a name and description. In Figure 6-1, although attributes are not shown for the "Technology/Enhancement" high level object, an example set might be:

Option Set 1:	*Baseline Current Systems*
Option Set 2:	*Maximum Technologies*
Option Set 3:	*Information Systems Technologies Only*

6.4.2 Technology Modeling Using the OIA

The ability to model technology as described above could be accomplished in a slightly modified version of the current OIA. The concept of defining a hierarchy of technologies and their attributes, just described, could for the most part be accomplished in the current system. Technologies would be represented as objects along with facilities, vehicles, manpower, GSE etc. within the VDA. Figure 6-2 shows the current OIA system being used to define technology objects within the VDA. The attributes necessary to generate the reports mentioned above include the following:

Readiness Level:	1-10	Standard scale used by NASA to indicate what stage of development a current technology is at. One is the lowest and a value of 6-7 indicates flight readiness.
Information Sources:		List of references describing the technology or its readiness level
Cost to Reach Level 6:	$x	The cost in dollars required to develop the technology for flight or ground operational use.
Development Years Required:	19xx	The number of years required to develop the technology based on today's readiness level
Include As Part of Option 1: Include As Part of Option 2: ↓ Include As Part of Option n:	Y or N Y or N ↓ Y or N	Indicates whether or not the specific technology is part of each technology scenario or option set defined in the high level "Technologies /Enhancements" object

Note the last group of attributes, is not a typically defined object attribute. Each Option Set defined in the high-level "Technologies/Enhancements" object, i.e. "Baseline Technology", represents an individual Y or N (checkbox) attribute in a specific technology. The attribute names should be automatically derived from the high-level "Technologies/Enhancements" object.

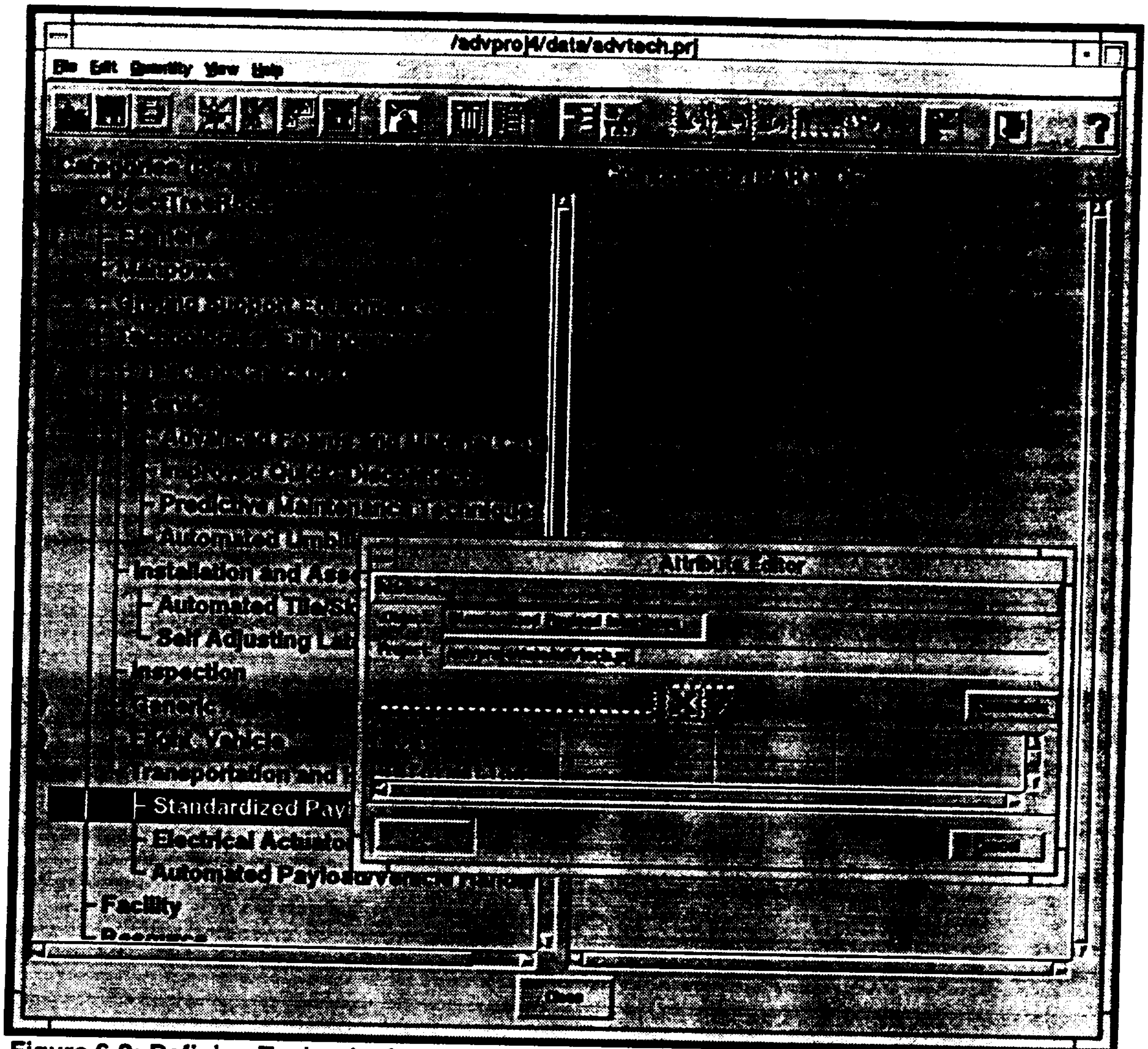

Figure 6-2: Defining Technologies In The OIA

Once technologies have been defined in the VDA they can be assigned as needed resources for given tasks. However, there is one major difference, and inherent change to the current OIA, necessary to represent tasks that make use of an enhanced method or technology. The difference is that optional tasks are needed. That is, for a given high-level task, there must be an ability to represent one or more optional sub-tasks which make use of various technologies or new methods. For instance, Figure 6-3 shows the script editor being used to define the sub-tasks for the "Subsystem Inspection" task. The sub-task "Inspect Control Surfaces" has a set of optional sub-tasks that each make use of a different method and corresponding technologies. The user must either select which of these methods will be used or use a "Task Selection Utility" to do this automatically. This utility would attempt to locate every task in the process, or current script, with optional sub-tasks and choose the valid option based on which of the available Technology Scenarios is currently in use. Note, it is not clear at this time how the current Technology Scenario would be represented. Also, in some cases two or more optional tasks would be valid under a given scenario. For instance, if the "Information System

Technologies" scenario was active, and both "Automated Image Processing Inspection" and "Automated Infrared Analysis" made use of technologies which were information systems technologies then they would both be valid. In this case the user would have to choose which optional method should be used. In most cases there will simply be two options, the baseline or current method and an improved method that requires some advanced technology.

Once the tasks are defined in a script their resources must be defined. Any task, whether it is part of a set of optional tasks or not, must have resources assigned, including which technologies are required if any. Figure 6-4 indicates how this would be accomplished for the optional subtask "Automated Image Processing Inspection."

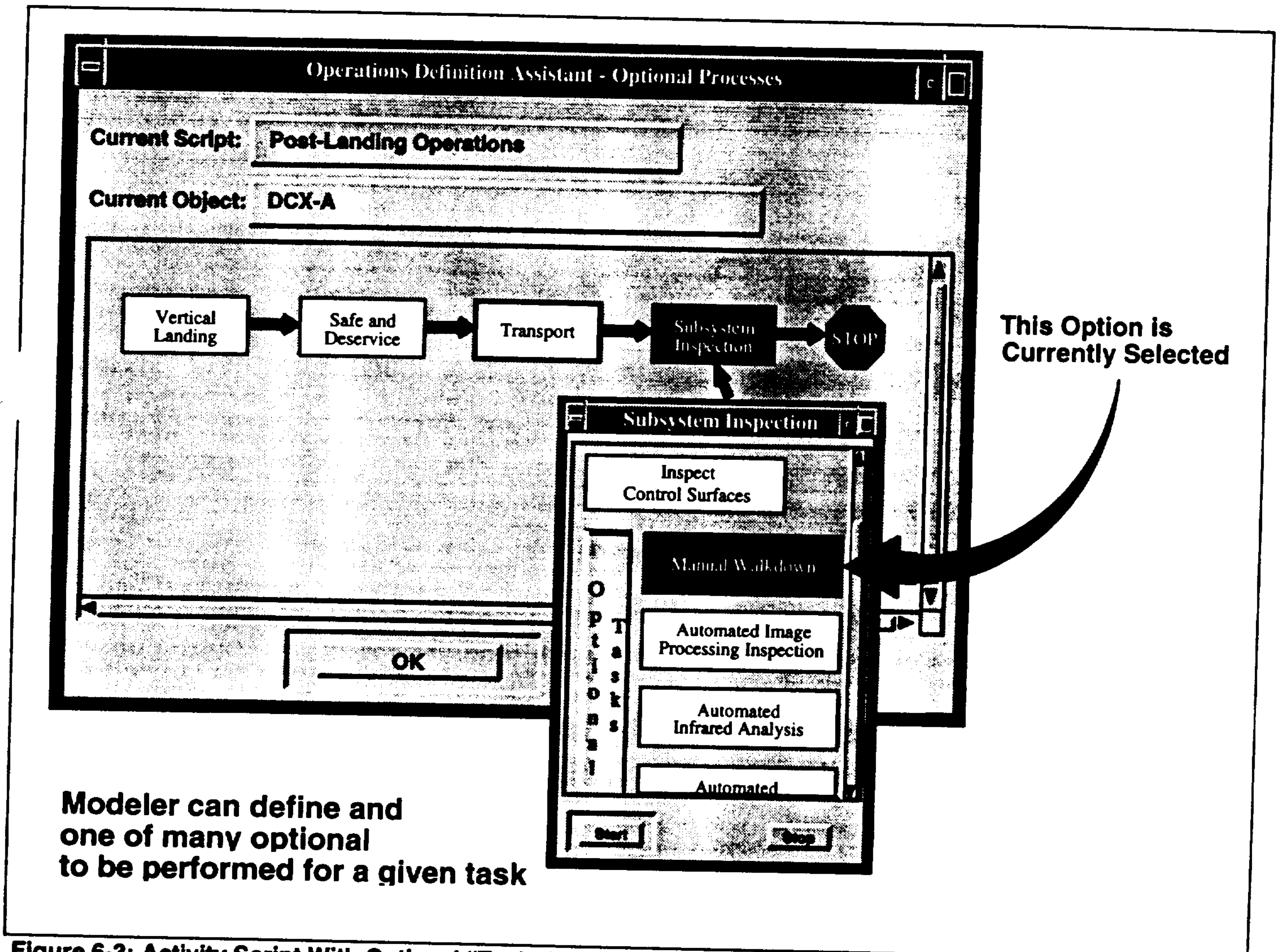

Figure 6-3: Activity Script With Optional "Technlogy Enhanced" Tasks

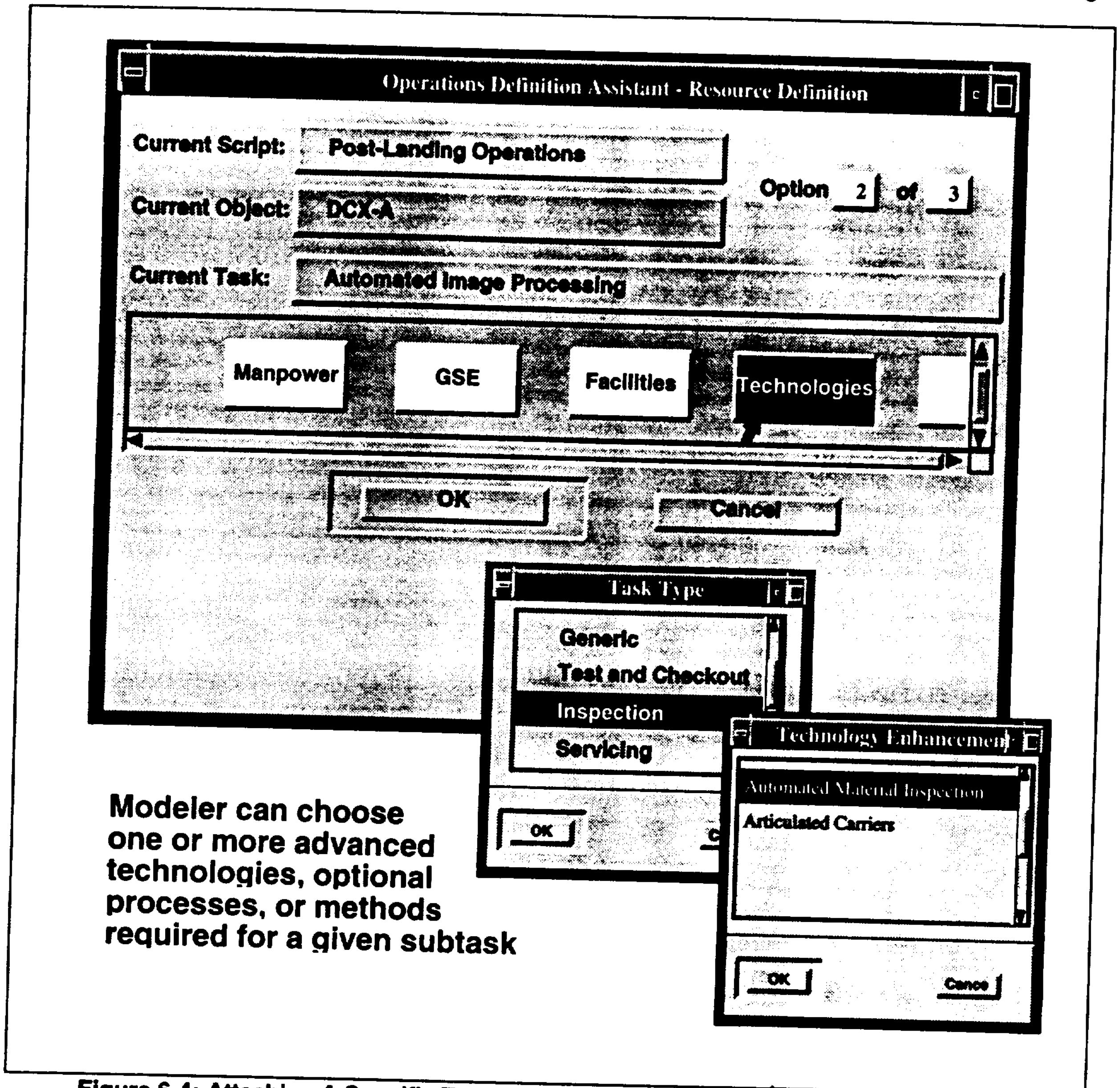

Figure 6-4: Attaching A Specific Technology To A Task As A Resource

Once all of the tasks have been defined and the optional sub-tasks selected for a particular scenario or Technology Set an assessment can be run and the needed reports, as shown above, can be generated. The desired technology scenario can be chosen by editing the attributes of the high-level "Technologies/Enhancements" object and simply selecting on of the Technology Scenario names to have a value of Y. For example, the attribute named "Maximum Technologies" could be set to Y. During the assessment, or before it is run, a validity function is executed to that checks to see that all optional sub-tasks currently chosen do not require any technologies or enhancements that are not part of the just selected Technology Scenario. If any are found the user must choose a different optional task before the assessment can be run. Note, this checking process could also take place during use of the ODA when scripts and tasks are being defined. However, it is necessary when assessments are run also in case a new technology scenario has been chosen.

Once an assessment is executed the Reporting Tool can be used to generated needed technology reports. All of the reports listed above in Section 6.4.1 should be available. Figure 6-5 illustrates two typical technology related reports. The report on the left illustrates the technologies required, when their development must be started assuming a given launch date, and the cost to develop each for a given technology scenario that is also listed on the report. The total technology development cost is also shown. The report on the right is a comparison of assessments run using different technology scenarios. For each assessment, the total expected labor cost for operations, and the serial flow time of the program or mission is shown. Note, this assumes that cost can be derived from manpower resource usage, which is not a current capability. Also note that this requires a more complex extension to the current OIA. It requires summary data taken from different assessments. This could be accomplished by storing certain attribute and report summary data values in a history log after each assessment. Once one or more assessments have been logged a comparison report can be generated.

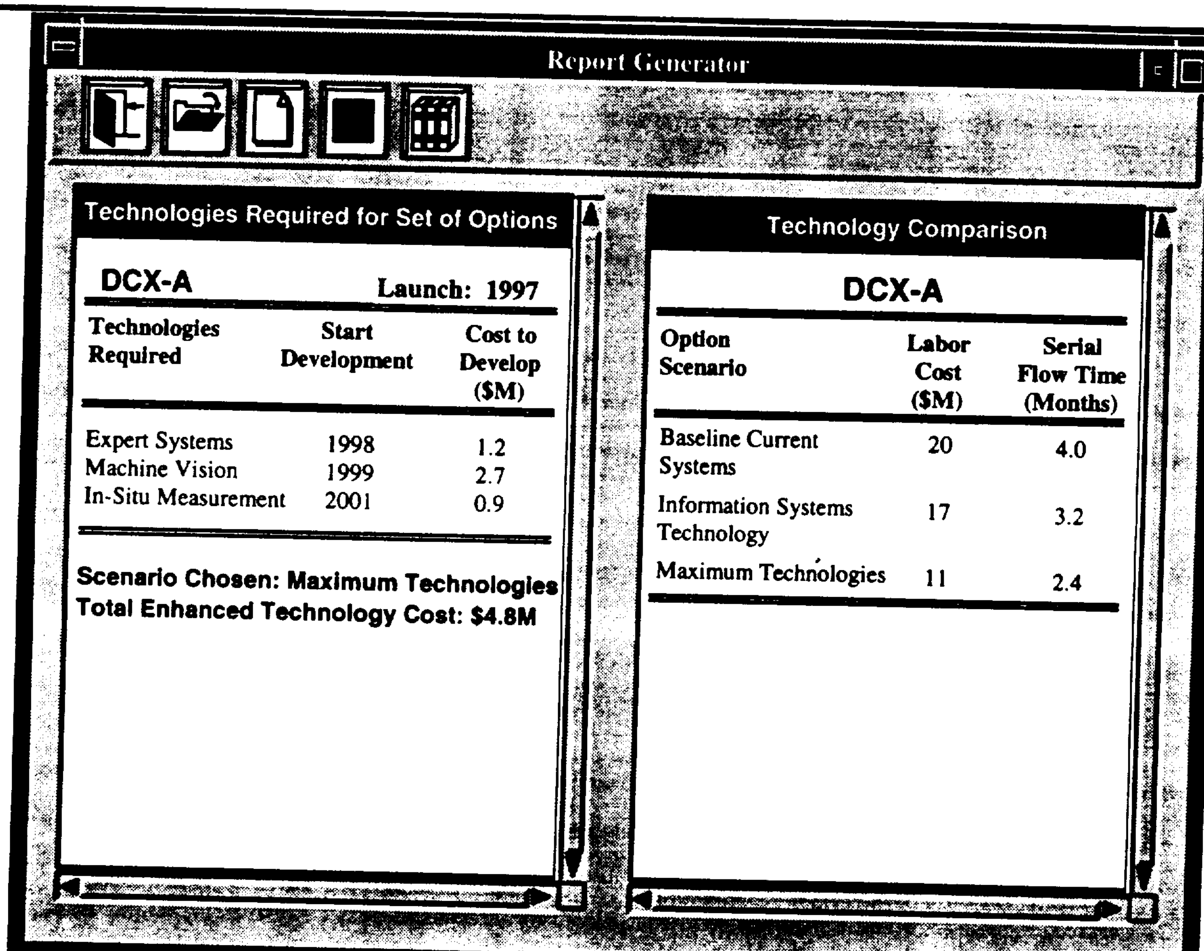

Figure 6-5: Typical Technology Information Report In An Enhanced OIA

6.4.3 Uses of this Methodology

The technology modeling capability just described provides powerful capabilities when assessing various spacecraft programs and needs. As mentioned earlier the comparison reports could be used to compare the benefits of implementing a particular technology development program to complete process that makes use of only existing methods and processes. This would provide, detailed, credible justifications for pursuing the development of a given set of technology programs. Because a number of various options can be assessed fairly quickly a number of justifications can be created for various slight differences in technology programs. For instance one could compare the effects of both a $5M artificial intelligence program that develops certain technologies, and a $20M program with additional technologies, on the X-33 program. In the past this could be done but the assessment time was extensive making it expensive to do and the number of options that could be chosen limited. This method provides a much greater capability to assess and represent technology information.

KSC Facility Attributes Menu

View Data In English Units

View Data In Metric Units

Enter Data In English Units

Select Facitity & Print Data In English Units

Select Facitity & Print Data In Metric Units

Sort and Print Facility List

APPENDIX
"A"

Return to Menu

Location	Facility No.	Name	Facility Type
KSC VAB Extended Area	L6-247	Manufacturing Building	Rocket motor construction
KSC VAB Area	K6-848	Vehicle Assembly Building (VAB)	Space vehicle assembly processing and integration
KSC VAB Area	K6-894	Orbiter Processing Facility High Bay 1 & 2 (OPF)	Orbiter processing, maintenance and payload
KSC VAB Area	K6-494	Rotation/Processing Building	Shuttle processing
KSC VAB Area	K6-794	Thermal Protection System Facility (TPS)	Office, shop and storage
KSC VAB Area	K6-994	Elevated Water Storage Tank	Water storage
KSC VAB Area	K6-995	Ground Storage Reservoir	Water storage
KSC VAB Area	K6-848	VAB High Bays 1 and 3	Space vehicle assembly processing and integration
KSC VAB Area	K6-848	VAB High Bays 2 and 4	Space vehicle assembly processing and integration
KSC VAB Area	K6-848	VAB Low Bay East and Low Bay West	Space vehicle assembly processing and integration
KSC VAB Area	K6-848	VAB High Bay and Low Bay Transfer Aisles	Space vehicle assembly processing and integration
KSC VAB Area	K6-848	VAB Towers (6)	Space vehicle assembly processing and integration
KSC VAB Area	K6-696	Orbiter Processing Facility High Bay 3 (OPF - HB 3)	Orbiter processing, maintenance and payload
KSC VAB Area	K6-894	Orbiter Processing Facility (OPF) Annex	Orbiter processing, maintenance and payload
KSC VAB Area	K6-894, K6-894A, K6-894B, K6-894D, K6-894F & K6-895	Orbiter Processing Facility Complex (OPF)	Orbiter processing, maintenance and payload
KSC VAB Area	K6-894A	OPF Environmental Control Building East	Orbiter processing, maintenance and payload
KSC VAB Area	K6-894B	OPF Environmental Control Building West	Orbiter processing, maintenance and payload
KSC VAB Area	K6-894D	OPF GSE Storage Building	Orbiter processing, maintenance and payload
KSC VAB Area	K6-894F	OPF Hazardeous Waste Storage Building	Orbiter processing, maintenance and payload
KSC VAB Area	K6-895	OPF Pump House	Orbiter processing, maintenance and payload
KSC Launch Complex Facility 39B	J7-140	High Pressure GN2 Facility	GN2 storage facility
KSC Launch Complex Facility 39A	J8-1462	High Pressure GN2 Facility	GN2 storage facility
KSC Launch Complex 39B	J7-491	Electrical Equipment Building No. 3 (Oxidizer)	Electrical Equipment
KSC Launch Complex 39B	J7-490	Hypergol Oxidizer Facility	Oxidizer Facility
KSC Launch Complex 39B	J7-535	Electrical Equipment Building No. 4 (Fuel)	Electrical Equipment

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Location	Facility No.	Name	Facility Type
KSC Launch Complex 39B	J7-182	LOX Facility	Liquid oxygen storage tank
KSC Launch Complex 39B	J7-132	Operations Support Building B - 1	Office and Shop
KSC launch Complex 39B	J7-192	LH2 Facility	Liquid hydrogen storage tank
KSC Launch Complex 39B	J7-231	Electrical Equipment Building No. 2 (LOX)	Electrical Equipment
KSC Launch Complex 39B	J7-241	Electrical Equipment Building No. 1 (RP - 1)	Electrical Equipment
KSC Launch Complex 39B	J7-242	Foam Building	Storage
KSC Launch Complex 39B	J7-288	Water Tank	Elevated water storage tank
KSC Launch Complex 39B	J7-292	RP-1 Facility	Storage
KSC Launch Complex 39B	J7-243	Operations Support Building B - 2 (LOX)	Shop
KSC Launch Complex 39B	J7-337	Launch Pad 39B	Space vehicle processing and launch
KSC Launch Complex 39B	J7-337 and various others (see attached).	Launch Complex 39A (LC-39B)	Space vehicle processing and launch
KSC Launch Complex 39B	J7-243A, J7-337A thru 377F and J7-377H	Boxcars	Tempory support facilities
KSC Launch Complex 39B	J7-384	Compressed Air Building	Mechanical Equipment
KSC Launch Complex 39B	J7-432	Remote Air Intake Building	Mechanical Equipment
KSC Launch Complex 39B	J7-534	Hypergol Fuel Facility	Fuel Facility
KSC Launch Complex 39B	J7-688	Operations Building No. 1	Personnel Office
KSC Launch Complex 39A	J8-1502	LOX Facility	Liquid oxygen storage tank
KSC launch Complex 39A	J8-1513	LH2 Facility	Liquid hydrogen storage tank
KSC Launch Complex 39A	J8-1610	Water Tank	Elevated water storage tank
KSC Launch Complex 39A	J8-1708 and various others (see attached).	Launch Complex 39A (LC-39A)	Space vehicle processing and launch
KSC Launch Complex 39A	J8-1613	RP-1 Facility	Storage
KSC Launch Complex 39A	J8-1503	Operations Support Building A - 1	Shop
KSC Launch Complex 39A	J8-1553	Electrical Equipment Building No. 2 (LOX)	Electrical Equipment
KSC Launch Complex 39A	J8-1563	Electrical Equipment Building No. 1 (RP - 1)	Electrical Equipment
KSC Launch Complex 39A	J8-1564	Foam Building	Storage

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Location	Facility No.	Name	Facility Type
KSC Launch Complex 39A	J8-1565	Pump House (RP-1)	Storage
KSC Launch Complex 39A	J8-1567	Cable Termination Building	Communications Equipment
KSC Launch Complex 39A	J8-1614	Operations Support Building (A-2)	Shop
KSC Launch Complex 39A	J8-1659	Compressed Air Building	Mechanical Equipment
KSC Launch Complex 39A	J8-1708	Launch Pad 39A	Space vehicle processing and launch
KSC Launch Complex 39A	J8-1708A thru 1708G and J8-1708I	Boxcars	Space vehicle processing and launch
KSC Launch Complex 39A	J8-1753	Remote Air Intake Building	Mechanical Equipment
KSC Launch Complex 39A	J8-1906	Hypergol Fuel Facility	Fuel Facility
KSC Launch Complex 39A	J8-2009	Operations Building No. 1	Personnel Office
KSC Launch Complex 39A	J8-1862	Hypergol Oxidizer Facility	Oxidizer Facility
KSC Launch Complex 39A	J8-1856	Electrical Equipment Building No. 4 (Fuel)	Electrical Equipment
KSC Launch Complex 39A	J8-1811	Electrical Equipment Building No. 3 (Oxidizer)	Electrical Equipment
KSC Industrial Area	M6-360	Space Station Processing Facility (SSPF)	Space Station element and payload processing
KSC Industrial Area	M7-355	Operations & Checkout Building (O&C)	Spacelab and spacelab payload processing
KSC Industrial Area	M7-1354	Payload Hazardous Servicing Facility (PHSF)	Hypergol testing
KSC Industrial Area	M7-1210	Spacecraft Assembly & Encapsulation Facility, No. 2	Hazardous payload servicing
KSC Industrial Area	M7-961, M7-1061, M7-1212, M7-1410, M7-1412	Hypergol Module Facility Complex (HMF)	Orbiter Hypergol module processing
KSC Industrial Area	M7-1469	Vertical Processing Facility	Payload/upper stage integration & testing
KSC Industrial Area	M7-961	HMF North Processing Building	Orbiter OMS Pod maintenance
KSC Industrial Area	M7-1212	HMF South Processing Building	Orbiter forward RCS module processing
KSC Industrial Area	M7-1412	HMF Storage Building East	Orbiter OMS Pod storage
KSC Industrial Area	M7-1410	HMF Storage Building West	Orbiter RCS Module storage
KSC Industrial Area	M7-1061	HMF Support Building	Hypergol module processing support
CCAFS	66250	SRB Recovery Building Hangar AF	Office & SRB Processing

turn to Menu

Facility Attributes
(English Units)

Facility Name Vehicle Assembly Building (VAB)

Location KSC VAB Area

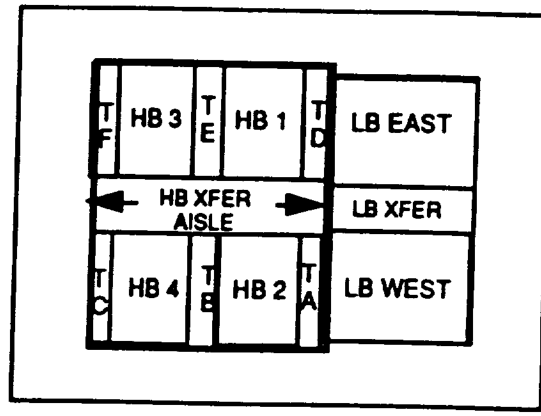
Facility No. K6-848

Facility Type Space vehicle assembly processing and integration (payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,831,105

Net usable floor space (sq. ft.) 1,702,551

Number of floors 42



CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$659,518,454		$5,747,780		60	

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	91,889	293,502	346,959	37,946	932,255	1,702,551

Description

The Vehicle Assembly Building (VAB) is capable of supporting the receiving, assembly, integration, test and checkout of the Space Shuttle elements. The VAB also provides external tank and orbiter main engine test, checkout and storage capabilities.

Within the VAB there are four high bays - Bays 1 through 4 - , six towers, a high bay transfer aisle, two low bays - Low Bay East and Low Bay West - and low bay transfer aisle. The transfer aisles run north and south connecting and transecting the high bay area from low bay area. In addition to the bridge cranes in the high bay and low bay areas there are more than 70 lifting devices in the VAB.

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Facility Attributes
(English Units)

Facility Name Orbiter Processing Facility High Bay 1 & 2 (OPF)

Location KSC VAB Area

Facility No. K6-894

Facility Type Orbiter processing, maintenance and payload integration
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 131,948

Net usable floor space (sq. ft.) 131,181

Number of floors 3

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$67,381,179		$4,792,664		55	

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	HB 1	HB 2	LB			
Apprv. for Expel.	No	No	No			
Prop Load Cap	No	No	No			
Floor Space (sq. ft.)	29,550	29,550	67,803			
Size (l x w x h)	197 150 95	197 150 95	233 97 25			
Door Size (w x h)	95 30	95 30				
No. Cranes	2	2	N/A			
Crane Cap (ton)	30	30				
Hook Ht (feet)	66	66				
Cleanliness (level)	100k	100k	100k			

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	26,085	65,952	8,837	8,506	21,801	131,181

Description

The OPF consists of two identical high bays connected by a low bay. Each high bay is equipped with two bridge cranes. The payload bay and orbiter crew cabin can be maintained at a cleanliness level100k.

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Facility Attributes

(English Units)

Facility Name Rotation/Processing Building

Location KSC VAB Area

Facility No. K6-494

Facility Type Shuttle processing
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 18,712

Net usable floor space (sq. ft.) 22,342

Number of floors 1

CofF (1992$) **R&D (1992$)** **M&R (1992$)** **Ops (1992$)** **M&R M/P** **Ops M/P**

Processing Areas:	**Area 1**	**Area 2**	**Area 3**	**Area 4**	**Area 5**	**Area 6**
Type (HB, AL, etc.)	HB 1					
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)	64					
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	2					
Crane Cap (ton)						
Hook Ht (feet)	200					
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.)						**Total**
Floor Space (sq. ft.)						

Description

Usable floor space is listed as being greater than the gross floor space!!? Better check this.

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Facility Attributes

(English Units)

Facility Name Thermal Protection System Facility (TPS)

Location KSC VAB Area

Facility No. K6-794

Facility Type Office, shop and storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 44,100

Net usable floor space (sq. ft.) 41,604

Number of floors 2

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$3,792,044					

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

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Facility Attributes
(English Units)

Facility Name Elevated Water Storage Tank

Location KSC VAB Area

Facility No. K6-994

Facility Type Water storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

The elevated water tank contains 250,000 gallons of water for fire suppression and deluge.

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Facility Attributes
(English Units)

Facility Name Ground Storage Reservoir

Location KSC VAB Area

Facility No. K6-995

Facility Type Water storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

Reservoir for storing 1,000,000 gallons of water used for the fire suppression and deluge.

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Facility Attributes
(English Units)

Facility Name Manufacturing Building

Location KSC VAB Extended Area

Facility No. L6-247

Facility Type Rocket motor construction
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 168,014

Net usable floor space (sq. ft.) 157,068

Number of floors 2

CofF (1992$) R&D (1992$) M&R (1992$) Ops (1992$) M&R M/P Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	3					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description
The Manufacturing Building has three bridge cranes. One 13.6 tonne (15 ton) crane, one 4.5 tonne (5 ton) crane and one 0.9 tonne (1 ton) crane.

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Facility Attributes

(English Units)

Facility Name Space Station Processing Facility (SSPF)

Location KSC Industrial Area

Facility No. M6-360

Facility Type Space Station element and payload processing
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

Under construction.

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Facility Attributes

(English Units)

Facility Name Operations & Checkout Building (O&C)

Location KSC Industrial Area

Facility No. M7-355

Facility Type Spacelab and spacelab payload processing
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 601,505

Net usable floor space (sq. ft.) 589,377

Number of floors 5

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$192,220,259					

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	HB					
Apprv. for Expel.	No					
Prop Load Cap	No					
Floor Space (sq. ft.)	46,768					
Size (l x w x h)	175 85 140					
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.)						Total
Floor Space (sq. ft.)						

Description

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Facility Attributes
(English Units)

Facility Name Payload Hazardous Servicing Facility (PHSF)

Location KSC Industrial Area

Facility No. M7-1354

Facility Type Hypergol testing
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 18,486

Net usable floor space (sq. ft.) 15,474

Number of floors 1

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$12,095,603					

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

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Facility Attributes

(English Units)

Facility Name Spacecraft Assembly & Encapsulation Facility, No. 2 (SAEF 2)

Location KSC Industrial Area

Facility No. M7-1210

Facility Type Hazardous payload servicing
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 17,098

Net usable floor space (sq. ft.) 17,486

Number of floors 2

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$22,217,807					

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	HB	AL	LB 1	LB 2	Test Cell	
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)	4,851	2,379	1,367	512		
Size (l x w x h)	99 49 74	58 41	72 19 25	27 19 44	37 37 52	
Door Size (w x h)	21 40	21 40			22 40	
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)	100k	300K	100K	100K		

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

Usable floor space is listed as being greater than the gross floor space!!? Better check this.

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Facility Attributes
(English Units)

Facility Name Hypergol Module Facility Complex (HMF)

Location KSC Industrial Area

Facility No. M7-961, M7-1061, M7-1212, M7-1410, M7-1412

Facility Type Orbiter Hypergol module processing
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors See description.

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$28,070,930		$877,780		27	

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

The Hypergol Maintenance Facility complex comprises a group of buildings providing all the facilities required to maintain, modify and store Hypergol modules that are removed periodically from the Orbiter. These buildings are: Hypergol Module Processing North Building (M7-961); Hypergol Module Support Building (M7-1061); Hypergol Module Processing South Building (M7-1212); Hypergol Storage Building West (M7-1410); Hypergol Storage Building East (M7-1412).

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Facility Attributes

(English Units)

Facility Name Vertical Processing Facility

Location KSC Industrial Area

Facility No. M7-1469

Facility Type Payload/upper stage integration & testing
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 26,940

Net usable floor space (sq. ft.) 21,641

Number of floors 1

CofF (1992$) **R&D (1992$)** **M&R (1992$)** **Ops (1992$)** **M&R M/P** **Ops M/P**

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)	10,508					
Size (l x w x h)	95					
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.)						Total
Floor Space (sq. ft.)						

Description

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Facility Attributes

(English Units)

Facility Name LOX Facility

Location KSC Launch Complex 39A

Facility No. J8-1502

Facility Type Liquid oxygen storage tank
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

Capacity - 3,405,906 liters (900,000 gallons).

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Facility Attributes

(English Units)

Facility Name LH2 Facility

Location KSC launch Complex 39A

Facility No. J8-1513

Facility Type Liquid hydrogen storage tank
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

Capacity - 3,217,250 liters (850,000 gallons).

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Facility Attributes
(English Units)

Facility Name Water Tank

Location KSC Launch Complex 39A

Facility No. J8-1610

Facility Type Elevated water storage tank
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

The elevated water tank contains 1,135,320 liters (300,000 gallons) of water for fire and launch deluge.

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Facility Attributes

(English Units)

Facility Name HMF North Processing Building

Location KSC Industrial Area

Facility No. M7-961

Facility Type Orbiter OMS Pod maintenance
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 10,309

Net usable floor space (sq. ft.) 9,836

Number of floors 2

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	East HB	West HB	Support Area			
Apprv. for Expel.	No	No	No			
Prop Load Cap	No	No	No			
Floor Space (sq. ft.)	2,824	2,824	4,198			
Size (l x w x h)	40 40 50	40 40 50	140 47 12			
Door Size (w x h)	20 40	20 40				
No. Cranes	1	1	N/A			
Crane Cap (ton)	20	20				
Hook Ht (feet)	45	45				
Cleanliness (level)	N/A	N/A	N/A			

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	286	5,647	1,065	628	2,210	9,836

Description

The Hypergol Module Processing North Building (M7-961) is where maintenance is performed on the OMS Pods.

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Facility Attributes
(English Units)

Facility Name HMF South Processing Building

Location KSC Industrial Area

Facility No. M7-1212

Facility Type Orbiter forward RCS module processing
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 6,549

Net usable floor space (sq. ft.) 5,648

Number of floors 2

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1			Area 2			Area 3			Area 4	Area 5	Area 6
Type (HB, AL, etc.)	East HB			West HB			Support Area					
Apprv. for Expel.	No			No			No					
Prop Load Cap	No			No			No					
Floor Space (sq. ft.)	1,118			1,118			3,413					
Size (l x w x h)	40	40	50	40	40	50	70	30	27			
Door Size (w x h)	20	40		20	40							
No. Cranes	1			1			N/A					
Crane Cap (ton)	20			20								
Hook Ht (feet)	45			45								
Cleanliness (level)	N/A			N/A			N/A					

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		2,235	2,205		1,208	5,648

Description

The Hypergol Module Processing South Building (M7-1212) is where maintenance on the forward RCS module is performed.

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Facility Attributes
(English Units)

Facility Name HMF Storage Building East

Location KSC Industrial Area

Facility No. M7-1412

Facility Type Orbiter OMS Pod storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,700

Net usable floor space (sq. ft.) 1,809

Number of floors 1

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	Storage					
Apprv. for Expel.	No					
Prop Load Cap	No					
Floor Space (sq. ft.)	1,809					
Size (l x w x h)	75 43					
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)	N/A					

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)			1,707		102	1,809

Description
The Hypergol Storage Building East (M7-1412) is where the OMS Pods are stored..

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Facility Attributes
(English Units)

Facility Name HMF Storage Building West

Location KSC Industrial Area

Facility No. M7-1410

Facility Type Orbiter RCS Module storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,954

Net usable floor space (sq. ft.) 2,291

Number of floors 1

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1		Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)		Storage					
Apprv. for Expel.		No					
Prop Load Cap		No					
Floor Space (sq. ft.)		2,391					
Size (l x w x h)	73	45					
Door Size (w x h)							
No. Cranes		N/A					
Crane Cap (ton)							
Hook Ht (feet)							
Cleanliness (level)		N/A					

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)			2,391			2,391

Description

The Hypergol Storage Building West (M7-1410) is where the forward RCS modules are stored..

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Facility Attributes

(English Units)

Facility Name HMF Support Building

Location KSC Industrial Area

Facility No. M7-1061

Facility Type Hypergol module processing support
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 11,265

Net usable floor space (sq. ft.) 15,544

Number of floors 1

CofF (1992$) **R&D (1992$)** **M&R (1992$)** **Ops (1992$)** **M&R M/P** **Ops M/P**

Processing Areas:	**Area 1**	**Area 2**	**Area 3**	**Area 4**	**Area 5**	**Area 6**
Type (HB, AL, etc.)	Support					
Apprv. for Expel.	No					
Prop Load Cap	No					
Floor Space (sq. ft.)	15,544					
Size (l x w x h)	230 65					
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)	N/A					

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	**Total**
Floor Space (sq. ft.)	2,857	5,271	166	2,431	4,819	15,544

Description

The Hypergol Module Support Building (M7-1061) houses the support personnel and LPS consoles to provide monitoring and control of all HMF functions. The LPS consoles interface with the LPS Central Data Subsystem in the LCC and the hardware interface module in M7-961 and M7-1212.

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Facility Attributes

(English Units)

Facility Name VAB High Bays 1 and 3

Location KSC VAB Area

Facility No. K6-848

Facility Type Space vehicle assembly processing and integration
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	HB 1	HB 3				
Apprv. for Expel.	No	No				
Prop Load Cap	No	No				
Floor Space (sq. ft.)	30,000	30,000				
Size (l x w x h)	200 150 475	200 150 475				
Door Size (w x h)	76 456	76 456				
No. Cranes	1	1				
Crane Cap (ton)	325	325				
Hook Ht (feet)	462	462				
Cleanliness (level)	N/A	N/A				

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

The high bay area is divided into four sections. The two bays facing east - Bays 1 and 3 - are used for vertical assembly of Space Shuttle vehicles atop the Mobile Launch Platform (MLP). SRB stacking, SRB/ET mate and Orbiter/ET mate occurs in these two high bays.

The two bridge cranes in the high bay area have been (or will be) replaced with new cranes that have a capacity of 295 tonnes (325 ıns). One crane serves high bays 1 and 2 and the other serves high bays 3 and 4.

The high bays have upper and lower doors. The combined height is 456 ft. The lower door is 192 ft. wide and 114 ft. high. The upper door is 76 ft. wide and 342 ft. high.

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Facility Attributes

(English Units)

Facility Name VAB High Bays 2 and 4

Location KSC VAB Area

Facility No. K6-848

Facility Type Space vehicle assembly processing and integration
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	HB 2	HB 4				
Apprv. for Expel.	No	No				
Prop Load Cap	No	No				
Floor Space (sq. ft.)	30,000	30,000				
Size (l x w x h)	200 150 475	200 150 475				
Door Size (w x h)	76 456	76 456				
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)	N/A	N/A				

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

The two high bays on the west side of the VAB - bays 2 and 4 - is where External Tank (ET) checkout and storage takes place.

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Facility Attributes
(English Units)

Facility Name VAB Low Bay East and Low Bay West

Location KSC VAB Area

Facility No. K6-848

Facility Type Space vehicle assembly processing and integration (payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	LB East	LB West				
Apprv. for Expel.	No	No				
Prop Load Cap	No	No				
Floor Space (sq. ft.)	49,400	49,400				
Size (l x w x h)	260 190 210	260 190 210				
Door Size (w x h)						
No. Cranes	1					
Crane Cap (ton)	175					
Hook Ht (feet)	166					
Cleanliness (level)	N/A	N/A				

Support Areas: (Office, Lab, Shop, etc.)						Total
Floor Space (sq. ft.)						

Description

Low bay east contains the Shuttle Main Engine shop and servers as a holding area for Solid Rocket Boosters (SRB) forward assemblies and aft skirts. Low bay west is used for SRB refurbushment. The low bay area has a 175 ton bridge that transverses the combined length of the transfer aisles.

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Facility Attributes
(English Units)

Facility Name VAB High Bay and Low Bay Transfer Aisles

Location KSC VAB Area

Facility No. K6-848

Facility Type Space vehicle assembly processing and integration
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1			Area 2			Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	HB Xfer Aisle			LB Xfer Aisle						
Apprv. for Expel.	No			No						
Prop Load Cap	No			No						
Floor Space (sq. ft.)	39,292			23,920						
Size (l x w x h)	418	94	475	260	92	210				
Door Size (w x h)	56	53		55	94					
No. Cranes										
Crane Cap (ton)										
Hook Ht (feet)										
Cleanliness (level)	N/A			N/A						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

The transfer aisles that transects the high and low bay areas permit easy movement of vehicle stages, and elements.

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Facility Attributes

(English Units)

Facility Name VAB Towers (6)

Location KSC VAB Area

Facility No. K6-848

Facility Type Space vehicle assembly processing and integration (payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors 42

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
				12	

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	Tower A	Tower B	Tower C	Tower D	Tower E	Tower F
Apprv. for Expel.	No	No	No	No	No	No
Prop Load Cap	No	No	No	No	No	No
Floor Space (sq. ft.)	294,000	294,000	294,000	294,000	294,000	294,000
Size (l x w x h)	200 35 525	200 35 525	200 35 525	200 35 525	200 35 525	200 35 525
Door Size (w x h)						
No. Cranes	1		1			1
Crane Cap (ton)	325		325			175
Hook Ht (feet)	462		462			166
Cleanliness (level)	N/A	N/A	N/A	N/A	N/A	N/A

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

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Facility Attributes
(English Units)

Facility Name Orbiter Processing Facility High Bay 3 (OPF - HB 3)

Location KSC VAB Area

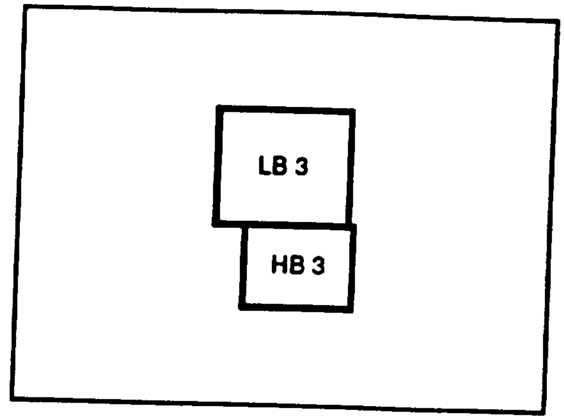
Facility No. K6-696

Facility Type Orbiter processing, maintenance and payload integration (payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 111,980

Net usable floor space (sq. ft.) 105,294

Number of floors 2



CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$12,198,380					

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	HB 3	LB 3				
Apprv. for Expel.	No	No				
Prop Load Cap	No	No				
Floor Space (sq. ft.)	29,250	50,400				
Size (l x w x h)	195 150 95	240 210 27				
Door Size (w x h)	95 35					
No. Cranes	2	N/A				
Crane Cap (ton)	30					
Hook Ht (feet)	66					
Cleanliness (level)	100k					

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	23,591	39,514	20,803	7,974	16,329	108,211

Description

Orbiter Processing Facility (OPF) High Bay 3 consists of a single high bay identical to OPF bays 1 and 2, and a low bay

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Facility Attributes
(English Units)

Facility Name Orbiter Processing Facility (OPF) Annex

Location KSC VAB Area

Facility No. K6-894

Facility Type Orbiter processing, maintenance and payload integration (payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.) 43,335

Number of floors 3

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	Annex					
Apprv. for Expel.	No					
Prop Load Cap	No					
Floor Space (sq. ft.)	43,335					
Size (l x w x h)	140 130 27					
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	39,475	2,093	1,767			43,335

Description

The OPF Annex is on the north side of K6-894.

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Facility Attributes
(English Units)

Facility Name Orbiter Processing Facility Complex (OPF)

Location KSC VAB Area

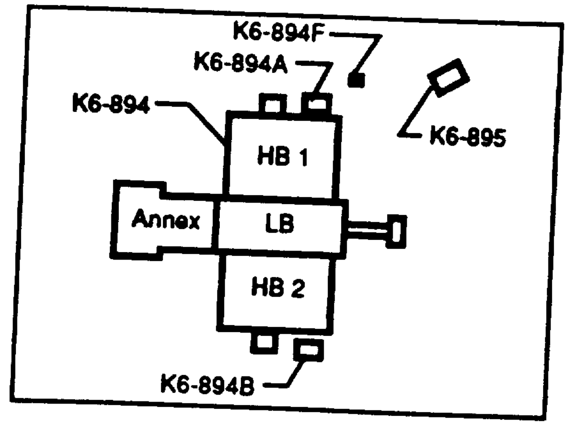
Facility No. K6-894, K6-894A, K6-894B, K6-894D, K6-894F & K6-895

Facility Type Orbiter processing, maintenance and payload integration (payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors



CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)						

Description

The OPF complex consists seven buildings. The main building K6- 894 contains two identical high bays connected by a low bay and an annex on the north side of the building. K6-696 provides a third high bay and an additional low bay. K6-894A and K6-894B are environmental control buildings on the east and west sides of K6-894. K6-894D is used to store GSE used in the OPF. K6-894F is a hazardous waste storage building. K6-895 is a pump house.

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Facility Attributes
(English Units)

Facility Name OPF Environmental Control Building East

Location KSC VAB Area

Facility No. K6-894A

Facility Type Orbiter processing, maintenance and payload integration (payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,498

Net usable floor space (sq. ft.) 1,390

Number of floors 1

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	K6-894A					
Apprv. for Expel.	No					
Prop Load Cap	No					
Floor Space (sq. ft.)	1,390					
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		138			1,252	1,390

Description

The environmental control buildings control the environmental conditions in the OPF K6-894.

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Facility Attributes
(English Units)

Facility Name OPF Environmental Control Building West

Location KSC VAB Area

Facility No. K6-894B

Facility Type Orbiter processing, maintenance and payload integration
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,498

Net usable floor space (sq. ft.) 1,390

Number of floors 1

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	K6-894B					
Apprv. for Expel.	No					
Prop Load Cap	No					
Floor Space (sq. ft.)	1,390					
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		138			1,252	1,390

Description
The environmental control buildings control the environmental conditions in the OPF K6-894.

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Facility Attributes

(English Units)

Facility Name OPF GSE Storage Building

Location KSC VAB Area

Facility No. K6-894D

Facility Type Orbiter processing, maintenance and payload integration
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 4,250

Net usable floor space (sq. ft.) 4,031

Number of floors 1

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	K6-894D					
Apprv. for Expel.	No					
Prop Load Cap	No					
Floor Space (sq. ft.)	4,031					
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)			4,031			4,031

Description

K6-894D provides storage space for GSE used in the OPF K6-894.

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Facility Attributes
(English Units)

Facility Name OPF Hazardeous Waste Storage Building

Location KSC VAB Area

Facility No. K6-894F

Facility Type Orbiter processing, maintenance and payload integration (payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.) 145

Number of floors 1

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	K6-894F					
Apprv. for Expel.	No					
Prop Load Cap	No					
Floor Space (sq. ft.)	145					
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)			145			145

Description

K6-894D provides storage space for hazardous waste from the OPF K6-894.

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Facility Attributes
(English Units)

Facility Name OPF Pump House

Location KSC VAB Area

Facility No. K6-895

Facility Type Orbiter processing, maintenance and payload integration
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 3,367

Net usable floor space (sq. ft.) 3,201

Number of floors 1

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	K6-895					
Apprv. for Expel.	No					
Prop Load Cap	No					
Floor Space (sq. ft.)	3,201					
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)					3,201	3,201

Description
K6-895 is the pump house for the OPF deluge system.

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Facility Attributes
(English Units)

Facility Name Launch Complex 39A (LC-39A)

Location KSC Launch Complex 39A

Facility No. J8-1708 and various others (see attached).

Facility Type Space vehicle processing and launch
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$243,731,027		$9,386,183			

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

Launch Complex 39A is roughly octagonal in shape and covers about 0.25-square-mile of land. Space Shuttles launch from the top of the concrete hardstand in the center of the pad. Propellant storage facilities are provided at the pad. A 900,000-gallon tank situated in the northwest corner of the pad stores the liquid oxygen, which is used as the oxidizer for the orbiter's main engines. Two pump supply 1,20 gallons of oxidizer per minute each to transfer the liquid oxygen from the storage tank to the orbiter's external tank. 850,000-gallon storage tank at the northeast corner of the pad store the liquid hydrogen fuel for the orbiter's main engines. ıypergol propellants used by the orbiter's Orbital Maneuvering engines and Reaction Control Thrusters are stored at the pad. The monomethyl hydrazine fuel is stored in a facility in the southeast corner of the pad and the oxidizer, nitrogen tetroxide is stored in a facility in the southwest corner of the pad. A 300,000-gallon elevated tank stores the water used for fire and launch deluge.

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Facility Attributes
(English Units)

Facility Name RP-1 Facility

Location KSC Launch Complex 39A

Facility No. J8-1613

Facility Type Storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,286

Net usable floor space (sq. ft.) 1,141

Number of floors

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)			1,141			1,141

Description

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Facility Attributes
(English Units)

Facility Name High Pressure GN2 Facility

Location KSC Launch Complex Facility 39B

Facility No. J7-140

Facility Type GN2 storage facility
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

Four rows of 18 compressed gas bottles for storage of 1,600 SCF water volume of gaseous nitrogen.

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Facility Attributes

(English Units)

Facility Name Operations Support Building A - 1

Location KSC Launch Complex 39A

Facility No. J8-1503

Facility Type Shop
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 944

Net usable floor space (sq. ft.) 844

Number of floors N/A

CofF (1992$) **R&D (1992$)** **M&R (1992$)** **Ops (1992$)** **M&R M/P** **Ops M/P**

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	91		639		114	844

Description

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Facility Attributes
(English Units)

Facility Name Electrical Equipment Building No. 2 (LOX)

Location KSC Launch Complex 39A

Facility No. J8-1553

Facility Type Electrical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 461

Net usable floor space (sq. ft.) 377

Number of floors N/A

CofF (1992$) **R&D (1992$)** **M&R (1992$)** **Ops (1992$)** **M&R M/P** **Ops M/P**

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		377				377

Description

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Facility Attributes
(English Units)

Facility Name Electrical Equipment Building No. 1 (RP - 1)

Location KSC Launch Complex 39A

Facility No. J8-1563

Facility Type Electrical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 551

Net usable floor space (sq. ft.) 459

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		459				459

Description

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Facility Attributes
(English Units)

Facility Name Foam Building

Location KSC Launch Complex 39A

Facility No. J8-1564

Facility Type Storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 150

Net usable floor space (sq. ft.) 120

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		120				120

Description

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Facility Attributes
(English Units)

Facility Name Pump House (RP- 1)

Location KSC Launch Complex 39A

Facility No. J8-1565

Facility Type Storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 235

Net usable floor space (sq. ft.) 205

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)			205			205

Description
Railway tanker off-loading.

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Facility Attributes
(English Units)

Facility Name Cable Termination Building

Location KSC Launch Complex 39A

Facility No. J8-1567

Facility Type Communications Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 124

Net usable floor space (sq. ft.) 100

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		100				100

Description

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Facility Attributes
(English Units)

Facility Name Operations Support Building (A - 2)

Location KSC Launch Complex 39A

Facility No. J8-1614

Facility Type Shop
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,278

Net usable floor space (sq. ft.) 1,159

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	245	792			122	1,159

Description

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Facility Attributes
(English Units)

Facility Name Compressed Air Building

Location KSC Launch Complex 39A

Facility No. J8-1659

Facility Type Mechanical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 562

Net usable floor space (sq. ft.) 500

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		500				500

Description

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Facility Attributes
(English Units)

Facility Name Launch Pad 39A

Location KSC Launch Complex 39A

Facility No. J8-1708

Facility Type Space vehicle processing and launch
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 66,211

Net usable floor space (sq. ft.) 46,169

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	1					
Crane Cap (ton)	25					
Hook Ht (feet)	250					
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	1,110	28,395	947	1,952	13,765	46,169

Description

The Pad A hardstand is 48 feet above sea level and is 490 feet long, 58 feet wide and 40 feet high. The flame trench divides it lengthwise from ground level to the pad surface. The Fixed Service Structure and the Rotating Support Structure is located on the north side of the hardstand. It i s open frame work about 40 feet square. A hammer head crane on the top provides hosting services as required in pad operations. The fixed structure has an Orbiter Access Arm, the External Tank Hydrogen Vent Access Arm and an :ternal Tank Gaseous Oxygen Vent Access Arm. The height to the top of the structure is 247 feet, while the height to the to of the ane is 265 feet. The Rotating Support Structure provides protection for the orbiter and access to the payload bay for installation and servicing payloads at the pad. It pivots through one third of a circle, from a retracted position well away from the orbiter to where its payload changeout room doors meet and match orbiter payload bay doors and provides five access levels from the 59-foot level to 189 feet above the pad floor.

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Facility Attributes
(English Units)

Facility Name Boxcars

Location KSC Launch Complex 39A

Facility No. J8-1708A thru 1708G and J8-1708I

Facility Type Space vehicle processing and launch
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 28,593

Net usable floor space (sq. ft.) 23,161

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	5,959	390	3,501	9,322	3,989	23,161

Description
Sixty boxcars for temporary support areas.

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Facility Attributes
(English Units)

Facility Name Remote Air Intake Building

Location KSC Launch Complex 39A

Facility No. J8-1753

Facility Type Mechanical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,400

Net usable floor space (sq. ft.) 1,220

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		1,220				1,220

Description

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Facility Attributes

(English Units)

Facility Name Electrical Equipment Building No. 3 (Oxidizer)

Location KSC Launch Complex 39B

Facility No. J7-491

Facility Type Electrical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 385

Net usable floor space (sq. ft.) 352

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		352				352

Description

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Facility Attributes

(English Units)

Facility Name Hypergol Oxidizer Facility

Location KSC Launch Complex 39B

Facility No. J7-490

Facility Type Oxidizer Facility
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 3,200

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)						

Description

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Facility Attributes

(English Units)

Facility Name Hypergol Fuel Facility

Location KSC Launch Complex 39A

Facility No. J8-1906

Facility Type Fuel Facility
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 2,720

Net usable floor space (sq. ft.) 2,160

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		2,160				2,160

Description

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Facility Attributes

(English Units)

Facility Name Operations Building No. 1

Location KSC Launch Complex 39A

Facility No. J8-2009

Facility Type Personnel Office
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 5,120

Net usable floor space (sq. ft.) 4,545

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	3,418			141	986	4,545

Description

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Facility Attributes
(English Units)

Facility Name LOX Facility

Location KSC Launch Complex 39B

Facility No. J7-182

Facility Type Liquid oxygen storage tank
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description
Capacity - 3,405,906 liters (900,000 gallons).

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Facility Attributes
(English Units)

Facility Name Operations Support Building B - 1

Location KSC Launch Complex 39B

Facility No. J7-132

Facility Type Office and Shop
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 944

Net usable floor space (sq. ft.) 840

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	91			635	114	840

Description

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Facility Attributes
(English Units)

Facility Name LH2 Facility

Location KSC launch Complex 39B

Facility No. J7-192

Facility Type Liquid hydrogen storage tank
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description
Capacity - 3,217,250 liters (850,000 gallons).

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Facility Attributes
(English Units)

Facility Name Electrical Equipment Building No. 2 (LOX)

Location KSC Launch Complex 39B

Facility No. J7-231

Facility Type Electrical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 461

Net usable floor space (sq. ft.) 377

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		377				377

Description

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Facility Attributes
(English Units)

Facility Name Electrical Equipment Building No. 1 (RP - 1)

Location KSC Launch Complex 39B

Facility No. J7-241

Facility Type Electrical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 551

Net usable floor space (sq. ft.) 459

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		459				459

Description

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Facility Attributes
(English Units)

Facility Name Foam Building

Location KSC Launch Complex 39B

Facility No. J7-242

Facility Type Storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 150

Net usable floor space (sq. ft.) 120

Number of floors N/A

CofF (1992$) **R&D (1992$)** **M&R (1992$)** **Ops (1992$)** **M&R M/P** **Ops M/P**

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		120				120

Description

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Facility Attributes

(English Units)

Facility Name Water Tank

Location KSC Launch Complex 39B

Facility No. J7-288

Facility Type Elevated water storage tank
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	N/A					
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

The elevated water tank contains 1,135,320 liters (300,000 gallons) of water for fire and launch deluge.

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Facility Attributes

(English Units)

Facility Name RP-1 Facility

Location KSC Launch Complex 39B

Facility No. J7-292

Facility Type Storage
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,268

Net usable floor space (sq. ft.) 1,141

Number of floors

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)			1,141			1,141

Description

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Facility Attributes
(English Units)

Facility Name Operations Support Building B - 2 (LOX)

Location KSC Launch Complex 39B

Facility No. J7-243

Facility Type Shop
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,266

Net usable floor space (sq. ft.) 1,142

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	115			902	125	1,142

Description

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Facility Attributes
(English Units)

Facility Name Boxcars

Location KSC Launch Complex 39B

Facility No. J7-243A, J7-337A thru 377F and J7-377H

Facility Type Tempory support facilities
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 33,546

Net usable floor space (sq. ft.) 29,287

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	6,492	198	8,565	11,652	2,380	29,287

Description
Sixty-five boxcars used for temporary support areas.

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Facility Attributes
(English Units)

Facility Name Electrical Equipment Building No. 4 (Fuel)

Location KSC Launch Complex 39B

Facility No. J7-535

Facility Type Electrical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 384

Net usable floor space (sq. ft.) 352

Number of floors N/A

CofF (1992$) **R&D (1992$)** **M&R (1992$)** **Ops (1992$)** **M&R M/P** **Ops M/P**

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		369				369

Description

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Facility Attributes

(English Units)

Facility Name Launch Complex 39A (LC-39B)

Location KSC Launch Complex 39B

Facility No. J7-337 and various others (see attached).

Facility Type Space vehicle processing and launch
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$243,731,027		$9,025,413			

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description

Launch Complex 39B is roughly octagonal in shape and covers about 0.25-square-mile of land. Space Shuttles launch from the top of the concrete hardstand in the center of the pad. Propellant storage facilities are provided at the pad. A 900,000-gallon tank situated in the northwest corner of the pad stores the liquid oxygen, which is used as the oxidizer for the orbiter's main engines. Two oump supply 1,20 gallons of oxidizer per minute each to transfer the liquid oxygen from the storage tank to the orbiter's external tank. 850,000-gallon storage tank at the northeast corner of the pad store the liquid hydrogen fuel for the orbiter's main engines. /pergol propellants used by the orbiter's Orbital Maneuvering engines and Reaction Control Thrusters are stored at the pad. The monomethyl hydrazine fuel is stored in a facility in the southeast corner of the pad and the oxidizer, nitrogen tetroxide is stored in a facility in the southwest corner of the pad. A 300,000-gallon elevated tank stores the water used for fire and launch deluge.

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Facility Attributes

(English Units)

Facility Name Launch Pad 39B

Location KSC Launch Complex 39B

Facility No. J7-337

Facility Type Space vehicle processing and launch
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 57,580

Net usable floor space (sq. ft.) 46,428

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
or Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes	1					
Crane Cap (ton)	25					
Hook Ht (feet)	250					
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	648	27,195	947	1,952	13,765	44,507

Description

The Pad B hardstand is 53 feet above sea level and is 490 feet long, 58 feet wide and 40 feet high. The flame trench divides it lengthwise from ground level to the pad surface. The Fixed Service Structure and the Rotating Support Structure is located on the north side of the hardstand. It i s open frame work about 40 feet square. A hammer head crane on the top provides hosting services as required in pad operations. The fixed structure has an Orbiter Access Arm, the External Tank Hydrogen Vent Access Arm and an al Tank Gaseous Oxygen Vent Access Arm. The height to the top of the structure is 247 feet, while the height to the to of the s 265 feet. The Rotating Support Structure provides protection for the orbiter and access to the payload bay for installation and servicing payloads at the pad. It pivots through one third of a circle, from a retracted position well away from the orbiter to where its payload changeout room doors meet and match orbiter payload bay doors and provides five access levels from the 59-foot level to 189 feet above the pad floor.

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Facility Attributes
(English Units)

Facility Name Compressed Air Building

Location KSC Launch Complex 39B

Facility No. J7-384

Facility Type Mechanical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 562

Net usable floor space (sq. ft.) 500

Number of floors N/A

CofF (1992$) **R&D (1992$)** **M&R (1992$)** **Ops (1992$)** **M&R M/P** **Ops M/P**

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		500				500

Description

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Facility Attributes
(English Units)

Facility Name Remote Air Intake Building

Location KSC Launch Complex 39B

Facility No. J7-432

Facility Type Mechanical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 1,400

Net usable floor space (sq. ft.) 1,220

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		1,220				1,220

Description

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Facility Attributes
(English Units)

Facility Name Hypergol Oxidizer Facility

Location KSC Launch Complex 39A

Facility No. J8-1862

Facility Type Oxidizer Facility
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 2,700

Net usable floor space (sq. ft.) 2,160

Number of floors N/A

CofF (1992$) R&D (1992$) M&R (1992$) Ops (1992$) M&R M/P Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		2,160				2,160

Description

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Facility Attributes
(English Units)

Facility Name Electrical Equipment Building No. 4 (Fuel)

Location KSC Launch Complex 39A

Facility No. J8-1856

Facility Type Electrical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 320

Net usable floor space (sq. ft.) 369

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		369				369

Description

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Facility Attributes
(English Units)

Facility Name Electrical Equipment Building No. 3 (Oxidizer)

Location KSC Launch Complex 39A

Facility No. J8-1811

Facility Type Electrical Equipment
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 320

Net usable floor space (sq. ft.) 369

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)		369				369

Description

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Facility Attributes
(English Units)

Facility Name Hypergol Fuel Facility

Location KSC Launch Complex 39B

Facility No. J7-534

Facility Type Fuel Facility
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 2,720

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)						

Description

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Facility Attributes

(English Units)

Facility Name Operations Building No. 1

Location KSC Launch Complex 39B

Facility No. J7-688

Facility Type Personnel Office
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 5,064

Net usable floor space (sq. ft.) 4,487

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	3,097			401	989	4,487

Description

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Facility Attributes
(English Units)

Facility Name High Pressure GN2 Facility

Location KSC Launch Complex Facility 39A

Facility No. J8-1462

Facility Type GN2 storage facility
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.)

Net usable floor space (sq. ft.)

Number of floors N/A

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)						
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)						
Size (l x w x h)						
Door Size (w x h)						
No. Cranes						
Crane Cap (ton)						
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.						Total
Floor Space (sq. ft.)						

Description
Four rows of 18 compressed gas bottles for storage of 1,600 SCF water volume of gaseous nitrogen.

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Facility Attributes
(English Units)

Facility Name SRB Recovery Building Hangar AF

Location CCAFS

Facility No. 66250

Facility Type Office & SRB Processing
(payload processing, vehicle processing, support, etc.)

Total gross floor space (sq. ft.) 66,170

Net usable floor space (sq. ft.) 64,169

Number of floors 2

CofF (1992$)	R&D (1992$)	M&R (1992$)	Ops (1992$)	M&R M/P	Ops M/P
$11,268,359					

Processing Areas:	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Type (HB, AL, etc.)	HB					
Apprv. for Expel.						
Prop Load Cap						
Floor Space (sq. ft.)	26,818					
Size (l x w x h)	42					
Door Size (w x h)						
No. Cranes	2					
Crane Cap (ton)	40					
Hook Ht (feet)						
Cleanliness (level)						

Support Areas: (Office, Lab, Shop, etc.	Office/ Conference	Lab/Shop/Tech Area	Storage/ Logistics	Misc.	Excluded	Total
Floor Space (sq. ft.)	13,345	33,554	7,108	2,536	6,824	63,367

Description

The Solid Rocket Booster Disassembly Facility is located in Hangar AF at the Cape Canaveral Air Force Station on the eastern shore of the Banana River. Access to the Atlantic Ocean, from which the boosters are retrieved by ship after jettison during Shuttle launch phase, is provided by locks at Port Canaveral. A tributary channel from the Disassembly Facility ties in with the main channel on the Banana River to KSC. Recovery vessels tow the expended boosters into the Disassembly Facility's offloading area. Mobile gantry ranes lift the booster onto a standard-gage tracked dolly for safing and preliminary washing. The nose cone frustums and the parachutes are offloaded for processing at other facilities. The SRB casings are moved into the Disassembly Facility for disassembly to the level of major elements. The segments then under go final cleaning and stripping before they are shipped to the VAB by truck. From the VAB the segments are shipped by rail to the prime contractor for refurbishment and propellant loading.

Field Name	Field Type	Formula / Entry Option
Name	Text	
.ocation	Text	
Facility No.	Text	
Facility Type	Text	
Total gross floor space meters	Calculation (Number)	= Total gross floor space feet/10.76391175
Total gross floor space feet	Number	
Net usable floor space meters	Calculation (Number)	= Net usable floor space feet/10.76391175
Net usable floor space feet	Number	
Number of floors	Text	
CofF	Number	
RandD	Number	Only allow values of type: "Number"
MandR	Number	
Ops	Number	
MandR MP	Number	
Ops MP	Number	
Area 1 type	Text	
Area 1 floor space sq meters	Calculation (Number)	= Area 1 floor space sq ft/10.76391175
Area 1 floor space sq ft	Number	
Area 1 length meters	Calculation (Number)	= Area 1 length feet/3.280839
Area 1 length feet	Number	
Area 1 width meters	Calculation (Number)	= Area 1 width feet/3.280839
Area 1 width feet	Number	
,rea 1 height meters	Calculation (Number)	= Area 1 height feet/3.280839
Area 1 height feet	Number	
Area 1 door width meters	Calculation (Number)	= Area 1 width feet/3.280839
Area 1 door width feet	Number	
Area 1 door height meters	Calculation (Number)	= Area 1 door height feet/3.280839
Area 1 door height feet	Number	
Area 1 cranes number	Text	
Area 1 crane capacity tonnes	Calculation (Number)	= Area 1 crane capacity tons/1.102
Area 1 crane capacity tons	Number	
Area 1 crane hook height meters	Calculation (Number)	= Area 1 crane hook height feet /3.280839
Area 1 crane hook height feet	Number	
Area 1 Cleanliness	Text	
Description	Text	
Remarks	Text	
Area 2 type	Text	
Area 2 floor space sq meters	Calculation (Number)	= Area 2 floor space sq ft/10.76391175
Area 2 floor space sq ft	Number	
Area 2 length meters	Calculation (Number)	= Area 2 length feet/3.280839
Area 2 length feet	Number	
Area 2 width meters	Calculation (Number)	= Area 2 width feet/3.280839
\rea 2 width feet	Number	

Field Name	Field Type	Formula / Entry Option
Area 2 height meters	Calculation (Number)	= Area 2 height feet/3.280839
Area 2 height feet	Number	
Area 2 door width meters	Calculation (Number)	= Area 2 door width feet/3.280839
Area 2 door width feet	Number	
Area 2 door height meters	Calculation (Number)	= Area 2 door height feet/3.280839
Area 2 door height feet	Number	
Area 2 cranes number	Text	
Area 2 crane capacity tonnes	Calculation (Number)	= Area 2 crane capacity tons/1.102
Area 2 crane capacity tons	Number	
Area 2 crane hook height meters	Calculation (Number)	= Area 2 crane hook height feet/3.280839
Area 2 crane hook height feet	Number	
Area 2 Cleanliness	Text	
Area 3 type	Text	
Area 3 floor space sq meters	Calculation (Number)	= Area 3 floor space sq ft/10.76391175
Area 3 floor space sq ft	Number	
Area 3 length meters	Calculation (Number)	= Area 3 length feet/3.280839
Area 3 length feet	Number	
Area 3 width meters	Calculation (Number)	= Area 3 door width feet/3.280839
Area 3 width feet	Number	
Area 3 height meters	Calculation (Number)	= Area 3 door height feet/3.280839
Area 3 height feet	Number	
Area 3 door width meters	Calculation (Number)	= Area 3 width feet/3.280839
Area 3 door width feet	Number	
Area 3 door height meters	Calculation (Number)	= Area 3 height feet/3.280839
Area 3 door height feet	Number	
Area 3 cranes number	Text	
Area 3 crane capacity tonnes	Calculation (Number)	= Area 3 crane capacity ton/1.102
Area 3 crane capacity ton	Number	
Area 3 crane hook height meters	Calculation (Number)	= Area 3 crane hook height feet/3.280839
Area 3 crane hook height feet	Number	
Area 3 Cleanliness	Text	
Area 4 type	Text	
Area 4 floor space sq meters	Calculation (Number)	= Area 4 floor space sq ft/10.76391175
Area 4 floor space sq ft	Number	
Area 4 length meters	Calculation (Number)	= Area 4 length feet/3.280839
Area 4 length feet	Number	
Area 4 width meters	Calculation (Number)	= Area 4 width feet/3.280839
Area 4 width feet	Number	
Area 4 height meters	Calculation (Number)	= Area 4 height feet/3.280839
Area 4 height feet	Number	
Area 4 door width meters	Calculation (Number)	= Area 4 door width feet/3.280839
Area 4 door width feet	Number	
Area 4 door height meters	Calculation (Number)	= Area 4 door height feet/3.280839
Area 4 door height feet	Number	

Field Name	Field Type	Formula / Entry Option
Area 4 cranes number	Text	
Area 4 crane capacity tonnes	Calculation (Number)	= Area 4 crane capacity ton/1.102
Area 4 crane capacity ton	Number	
Area 4 crane hook height meters	Calculation (Number)	= Area 4 crane hook height feet/3.280839
Area 4 crane hook height feet	Number	
Area 4 Cleanliness	Text	
Area 5 type	Text	
Area 5 floor space sq meters	Calculation (Number)	= Area 5 floor space sq feet/10.76391175
Area 5 floor space sq feet	Number	
Area 5 length meters	Calculation (Number)	= Area 5 length feet/3.280839
Area 5 length feet	Number	
Area 5 width meters	Calculation (Number)	= Area 5 width feet/3.280839
Area 5 width feet	Number	
Area 5 height meters	Calculation (Number)	= Area 5 height feet/3.280839
Area 5 height feet	Number	
Area 5 door width meters	Calculation (Number)	= Area 5 door width feet/3.280839
Area 5 door width feet	Number	
Area 5 door height meters	Calculation (Number)	= Area 5 door height feet/3.280839
Area 5 door height feet	Number	
Area 5 cranes number	Text	
Area 5 crane capacity tonnes	Calculation (Number)	= Area 5 crane capacity ton/1.102
Area 5 crane capacity ton	Number	
Area 5 crane hook height meters	Calculation (Number)	= Area 5 crane hook height feet/3.280839
Area 5 crane hook height feet	Number	
Area 5 Cleanliness	Text	
Area 6 type	Text	
Area 6 floor space sq meters	Calculation (Number)	= Area 6 floor space sq feet/10.76391175
Area 6 floor space sq feet	Number	
Area 6 length meters	Calculation (Number)	= Area 6 length feet/3.280839
Area 6 length feet	Number	
Area 6 width meters	Calculation (Number)	= Area 6 width feet/3.280839
Area 6 width feet	Number	
Area 6 height meters	Calculation (Number)	= Area 6 height feet/3.280839
Area 6 height feet	Number	
Area 6 door width meters	Calculation (Number)	= Area 6 door width feet/3.280839
Area 6 door width feet	Number	
Area 6 door height meters	Calculation (Number)	= Area 6 door height feet/3.280839
Area 6 door height feet	Number	
Area 6 cranes number	Text	
Area 6 crane capacity tonnes	Calculation (Number)	= Area 6 crane capacity ton/1.102
Area 6 crane capacity ton	Number	
Area 6 crane hook height meters	Calculation (Number)	= Area 6 crane hook height feet/3.280839
Area 6 crane hook height feet	Number	

Field Name	Field Type	Formula / Entry Option
Area 6 Cleanliness	Text	
SA 1 type	Text	
SA 1 sq meters	Calculation (Number)	= SA 1 sq feet/10.76391175
SA 1 sq feet	Number	
SA 2 type	Text	
SA 2 sq meters	Calculation (Number)	= SA 2 sq feet/10.76391175
SA 2 sq feet	Number	
SA 3 type	Text	
SA 3 sq meters	Calculation (Number)	= SA 3 sq feet/10.76391175
SA 3 sq feet	Number	
SA 4 type	Text	
SA 4 sq meters	Calculation (Number)	= SA 4 sq feet/10.76391175
SA 4 sq feet	Number	
SA 5 type	Text	
SA 5 sq meters	Calculation (Number)	= SA 5 sq feet/10.76391175
SA 5 sq feet	Number	
Total support area sq meters	Calculation (Number)	= SA 1 sq meters+SA 2 sq meters+SA 3 sq meters+SA 4 sq meters+SA 5 sq meters
Total support area sq feet	Calculation (Number)	= SA 1 sq feet+SA 2 sq feet+SA 3 sq feet+SA 4 sq feet+SA 5 sq feet
PICTURE	Picture/Sound	
Area 1 expl	Number	
Area 2 expl	Number	
Area 3 expl	Number	
Area 4 expl	Number	
Area 5 expl	Number	
Area 6 expl	Number	
Area 1 prop	Number	
Area 2 prop	Number	
Area 3 prop	Number	
Area 4 prop	Number	
Area 5 prop	Number	
Area 6 prop	Number	

Appendix B

Technologies for Improved Processing of Future Launch Vehicles

A total of 43 technologies, all of which show promise for enhancing future vehicle processing, are described here. These are separated into a set of convenient technology categories as delineated by the headings.

Flight Equipment

B.1 Electro-Mechanical Actuators for Flight Control

There are extensive delays, and processing costs due to problems with leaking hydraulic actuators. This is especially true for the shuttle's APU system and the associated hydraulics which are used to control orbiter flight surfaces. Substituting compact, high-power, lightweight motorized actuators and associated mechanisms for hydraulic actuators would completely eliminate the need to test for leaks, replace lines and pumps just before launch and re-test the system so often.

SOURCE: STS Interview Database

B.2 Modular Propulsion System

The STS main engines are extremely complex systems requiring extensive time to diagnose problems and correct known problems and failures. A more modular system would allow easier diagnosis. For instance each turbopump could be a single unit. Any system error could always be traced to a single unit. Furthermore the system should be designed so each module can be accessed and removed and repaired as a unit. This would greatly alleviate the need for extensive time and labor to repair and diagnose engine problems.

SOURCE: RLV Operations Synergy Team

Inspection

B.3 Access Platform Proximity Sensors

All operations requiring lifting/handling of the orbiter or payloads (orbiter CG measurement, payload insertion, orbiter-ET mate etc.) usually require human spotters placed on almost all access platforms to ensure there are no collisions. This extensive use of human labor could be eliminated with the use of inexpensive proximity sensors placed on each access platform or any other potential obstacle. These sensors must indicate the closest distance between any part of the components being lifted and the platform itself. This must be accurate regardless of the material that is closest to the platform (MLI blanket, aluminum or steel structures, black tiles etc.). This technology is very similar to the proximity sensing skin technology being used to protect manipulator arms from collisions.

SOURCE: STS Interview Database

B.4 Articulated Camera/Scope Carriers

Extensive effort is normally required to provide contingency or planned access for visual inspection of a number of items in extremely cluttered areas. In many cases, this is difficult or impossible to gain human access and work-arounds are found. A portable arm-like device that could be rapidly deployed and used to safely position a small high-resolution video camera or other "scope-like" device within cluttered environments would alleviate the need for human access in these cases. The system would have to provide autonomous, collision-free motion to a desired area in order for this to be a safe operation. This would allow visual inspection of a much larger number of components and vehicle areas and reduce expensive, hazardous human access for every inspection required.

SOURCE: Space Station Ground Processing Study and STS Interview Database

B.5 Automated Leak Detection and Location

Processing delays, and in some cases, launch delays are often caused by fluid leaks. An improved system and set of sensors is needed to identify small leaks and their locations. Identifying small leaks directly as opposed to monitoring various pressures and supply volumes for reductions, would indicate leak problems much earlier. More importantly, knowing the location of the leak reduces the need for extensive, labor intensive searching. It also reduces the need for removing various components just to check for leaks. Potential methods of accomplishing this makes use of infra-red.lasers and gas refraction.

SOURCE: RLV Operations Synergy Team

B.6 Automated Material Inspection

Extensive labor and time are normally required to inspect material surfaces such as door radiators, protective blankets, or structural panels. Because these tasks are tedious, there is also the likelihood that certain defects will be missed by technicians. Instead, an automated system could be developed for these tasks. All of the above inspection tasks require a similar sensing device to be driven over the entire surface while maintaining a narrow range of relative distance and orientation. A single manipulation system and integrated set of material defect sensing tools could be used for all tasks. The system may be fully automated or it may simply identify anomalies and then provide high-resolution video images to an operator for further inspection.

SOURCE: STS Interview Database

B.7 Thermal Imaging

Thermal image sensing and intelligent processing of the data would allow quick detection of various failures. This could be used for identifying shorts in electrical panels or cables, and predicting failures of bearings in rotating actuators and pumps.

SOURCE: RLV Operations Synergy Team

Installation & Assembly

B.8 Self Adjusting Latches

See Auto-Aligning Payload Interfaces. The technology for individual latches is essentially the same.

SOURCE: STS Interview Database

B.9 Automated Tile/Skin Handling

Extensive labor is involved in inspection, on-line repair, removal; installation, and re-waterproofing of TPS tiles or skin components. A robotic system is needed which can automatically inspect the TPS components and perform most of the operations under the control of one or two system operators. To accomplish this, a manipulation system that can carry the required tooling and sensor systems to each tile or skin panel is required. A vision or other sensor system that can identify pits, voids, cracks, and discoloration's would be used to identify all problems. Automated alignment sensors are required to locate the tools with respect to the TPS components so they can be automatically handled. The TPS components must be designed ahead of time to handle automation; that is, they should have fiducial markings or guides for alignment, not require extremely precise positioning during installation, and all attachment hardware should be designed for compatibility with simple end-effector tooling.

SOURCE: STS Interview Database

Servicing & Deservicing

B.10 Advanced Foams and Material Coatings

The use of sprayed foam and coating materials primarily for thermal protection would alleviate a primary driver of processing time and labor costs. Current methods using customized, individual tiles for skin protection requires extraordinary processing effort. A single coated system would alleviate this.

SOURCE: STS Interview Database

B.11 Automated Umbilical Connectors

The connection of large, multi-line umbilical plates requires extensive labor, and is extremely hazardous. Numerous fluid, gas, cryogenic fluids, and electrical signals must pass through the vehicle interface and the ground source lines. Any reusable launch vehicle will have to make use of automated umbilical connect to achieve low cost operations. These umbilicals are typically extremely heavy and difficult to handle. An automated system would have to properly locate the umbilical carrier plate, and insert the plate such that all connectors are mated. The insertion forces would have to be monitored to ensure no damage occurs to the connector hardware.

SOURCE: STS Interview Database and RLV Operations Synergy Team

B.12 Improved Quick-Disconnects

Although some quick-disconnect mechanisms exist on electrical, data and fluid lines they tend to be difficult to handle and are often leaking. Improved mechanisms are required to automatically align the mating halves and reduce leaks. Although numerous umbilical operations will continue to be manual, well designed disconnects will provide the ability to manual and automated operations.

SOURCE: RLV Operations Synergy Team

B.13 Predictive Maintenance Techniques

Through the use of various monitoring methods and data analysis techniques component failures of certain devices can be predicted ahead of time. Rotating machinery, bearings, parts subject to wear all have noticeable changes well before the onset of failure. Predicting failures before they occur and perfoming the associated maintenance or repairs alleviates emergency failures at crucial times in an operational flow, and more importantly avoids the loss of other equipment and components which can occur when a certain device fails. Candidate methods include - vibration sensing and rotor dynamics monitoring for rotating shafts such as turbo-pumps, hydraulic pumps, air handlers etc.; ferrography of hydraulic fluids and lubricants to predict bearing failure, and thermography (thermal imaging) to detect excessive wear between contacting components. All of the monitored data must be analyzed via expert systems and other mathematical algorithms to predict failure. In addition to this specialized data must be stored and tracked in a data base to perform predictive maintenance.

SOURCE: RLV Operations Synergy Team

Test and Checkout Tasks

B.14 Automated Battery Checkout

A system that does not require manual intervention and several connect/disconnect operations to test the health of various battery systems would provided improved processing operations. An intelligent, portable field device could determine the charge level, load capacity, and the quality of all connections in a fully automated manner. This would reduce time and labor during late processing tasks and reduce the need to provide human access to battery locations, which can be difficult for certain vehicles.

SOURCE: STS Interview Database

B.15 In-Situ Measurement Systems

Pressure, temperature, gas detection and other measuring devices often require extensive installation, specialized GSE, and off-line calibration and test work in other facilities. This can be cumbersome and time-consuming. Instead, in-line gauges and devices could be used. These devices would not have to be hooked up to systems, and could be calibrated while they are installed in the vehicle, payload or GSE components. In-line calibration would not only save extensive labor and flow time but would also allow for more frequent calibration, especially just before critical operations.

SOURCE: STS Interview Database and Space Station Ground Processing Study

B.16 Intelligent Sensors

The current method of obtaining system data and information requires analog sensor devices. The analog signals are brought back to a central data acquisition point using individual cables for each sensors. Any problem with sensor data must be verified to ensure that the sensor is working properly and the cable and acquisition equipment are intact. This is extremely costly to maintain and is difficult to troubleshoot, especially during critical operations. Enhanced sensors which are complete digital data devices would alleviate these problems. Sensors that contain on-board provisions for analog to digital conversion, signal conditioning, and data monitoring would alleviate these problems. A digital device could read and write sensor data over standard data communication systems or networks, thus alleviating the need for extensive cabling. For instance, a fiber optic communication system could be used and a single fiber bundle (1 cable) is all that would be needed for thousands of sensors.

SOURCE: STS Interview Database

B.17 Wireless Signal/Data Communication

Wireless communications permitting data to be transmitted and received without physical connections, is an exploding commercial area. Standards and support systems have been established for a diverse set of products. These products work within buildings (local-area networks) or cover large areas (wide-area networks). Local systems may be private while large-area systems generally use public carriers.

Most of the KSC applications call for local-area systems, although the large KSC complex might also benefit from a wide-area system. Wireless communications provide the flexibility that is well suited to ground processing operations. Both infrared (IR) and radio frequency (RF) systems are available, with RF being more popular because it avoids line-of-sight limitations. However, operations at KSC are very RF-sensitive, and introduction of this technology around payloads requires certification. Wireless data communications would provide the ability to collect, obtain or store information at any location in the field. The costly process of configuring, installing and maintaining data lines would be eliminated with this technology.

SOURCE: Space Station Ground Processing Study

Transporting & Handling

B.18 Automated Payload/Vehicle Handling and Mating Systems

Extensive time and labor are always required when large payload and vehicle components must be inserted, removed from, or mated to each other. These operations usually require precise setting and measurement of the attachment fixtures before the mating is accomplished. The mating components are then brought together and aligned using specialized handling devices, such as the PGHM, or cranes and lifts. A number of technicians provide feedback to an operator who manually controls the motion and relative position of the devices. Each mating device, latch, hook, or other item must be visually monitored by one or more technicians. This is an extremely cumbersome process, requiring a large number of highly trained personnel. Instead, an automated system could be used to speed this operation up, reduce the likelihood of improperly loading any connection, and reduce the cost. The key element required is an inexpensive portable method of measuring the relative position and orientation between mating hooks and trunions and other male and female mating components. A sensing system that could provide this data to a centralized controller would enable automated final alignment of the components.

SOURCE: STS Interview Database

B.19 Electrical Actuators for GSE

Numerous cranes, lifts, mechanisms, and other equipment required to handle the Space Shuttle and its components make use of pneumatic and hydraulic actuation. This is done to save GSE development cost, to meet extensive load or speed requirements, or to meet cleanliness and hazard-proof requirements. Compact, high-torque motors which can meet cleanliness standards and are explosion-proof should be used for all future vehicles, facilities, and GSE. A technology advancement in this case is not necessary. For most systems, existing motors using brushless commutation and specialized magnets can meet these requirements. Thus, this becomes more of a processing enhancement or design guideline than a requirement for new technology.

SOURCE: STS Interview Database

B.20 Standardized Auto-Aligning Payload Interfaces

The interface between payloads and their GSE and flight carriers such as the shuttle orbiter bay require precision alignment and extensive efforts to ensure proper mating. The retention fittings and hooks which normally receive payload trunions or other mounting hardware must be precisely aligned before mating. During mating operations the relative displacement between payload and carrier components must be measured at each fitting. This is normally done by technicians located at each fitting. The data is then manually gathered and a single test engineer determines the next incremental move to make. The alternative to this is to have interface fittings which automatically align themselves during mate and allow for large misalignments during mating. Advanced mechanisms or inexpensive displacement sensors could be used to accomplish this.

SOURCE: RLV Operations Synergy Team

Generic Technologies

B.21 CAD Data Conversion

Since each computer-aided design (CAD) software vendor stores drawings and other data in proprietary formats, KSC may need to reformat the material to fit into a standard, or convert it to another proprietary format using software. The most popular standardized format is the Initial Graphic Exchange Specification (IGES). Popular proprietary formats include DXF and Intergraph. Unfortunately, format conversion usually causes significant data losses and there is no way at present to prevent this. However, data loss will be reduced if strict adherence to a set of standards can be maintained. Non geometric data may sometimes be stored in conventional databases or files. These data may be moved between systems with little or no loss.

Commercial conversion software is well developed and readily available either from CAD vendors or third-party vendors such as Octal. Suppliers can tune the conversion routines to substantially increase the translation fidelity.

SOURCE: Space Station Ground Processing Study

B.22 CAD/CAM Part Production

Components for both flight hardware and GSE can be automatically machined directly from digital CAD information. This provides a number of advantages. Errors due to manual machining can be greatly reduced and the quality of the machining is consistent throughout the parts. What is most important, however, is if the CAD files can be obtained and transferred to KSC facilities, the part can always be fabricated locally. This alleviates the time-consuming and costly process of obtaining parts from distant facilities or firms no longer in business. A number of commercial vendors provide products that produce machine tool program code from CAD model data. However, generating tool cutter paths from a given shape is extremely difficult. This is especially true for complex parts. The more complex parts that can be handled by this technology, the greater the savings and other benefits would be.

SOURCE: Space Station Ground Processing Study

B.23 Computer Graphic Visualization

Computer graphics technology includes two different areas, high-resolution images and graphical user interfaces. Generation of high-resolution images has been the primary focus of hardware developers.

Two different types of animation are typically done, high-resolution and real-time. In high-resolution animation, a video recorder captures a sequence of rendered images. In interactive animation, some resolution is sacrificed to enable immediate image manipulation. There is no single system that is best for both modes of operation; computer graphics systems must be optimized for their use. Computer graphics technology is mature but is still a dynamically developing area.

Virtual reality (VR) is a new development in computer graphics that permits the user to experience interactive artificial environments. Both two- and three-dimensional spaces may be created and viewed. In immersive VR, the user is cutoff from outside visual information and can interact with only the virtual world. In non-immersive VR, the user can see both the virtual and the real worlds. This is an infant technology but many effective demonstrations have shown a use for this technology at KSC. The DOD has mandated VR for training. Ames Research Center is the leading NASA institution for VR.

SOURCE: Space Station Ground Processing Study

B.24 Computer-Aided Logistics

Computer-aided logistics may include any software technology useful to operations. Definitive research and development has been performed for the DOD computer-aided acquisition and logistics (CALS) initiative. CALS specifications are built on a number of mature technologies and a set of newly developed technologies. Because of the wide scope of this initiative, there will be a long maturing process. For most installations, one can pick and choose from among the potential set of technologies. Generally, a number of separate products are installed, with each implementing a portion of the overall CALS specification rather than a turnkey system. Many companies, most notably Digital Equipment Corporation which has the DOD CALS integration contract, are developing CALS workstation and server products.

SOURCE: Space Station Ground Processing Study developed to improve the fidelity of the training experience. This research is readily available and can be included in CBT systems.

SOURCE: Space Station Ground Processing Study

B.27 Data Acquisition

To acquire data, an instrument that is usually connected to a computer collects and records information. KSC is a large user of data acquisition technology with an extensive set of local and remote sensing equipment. Data acquisition is a well developed technology but there are very few generic commercial systems. Instead, data acquisition systems are usually built by a vendor for a specific application by customizing a proprietary set of core modules. Unfortunately, these commercial systems often depend on using common commercial programmable logic controllers instead of the centralized control specified for payload processing. Data originate from readily available commercial sensors.

The Test, Checkout and Monitoring System (TCMS) being developed for the space station, uses virtual instruments like many modern data acquisition systems, . Virtual instruments display gauges and dials on a computer monitor. Also, at KSC small data acquisition systems are in common use. They consist of instruments installed in a PC or attached to an instrument bus such as IEEE 488. These small systems may use one of several commercial virtual instrument packages which permit the rapid construction of a specialized user interface.

SOURCE: Space Station Ground Processing Study

B.28 Data Compression

Data compression refers to any technology that permits a reduction in the amount of data needed to convey the same amount of information. There are a number of analog and digital methods that are readily available and controlled by standards. In particular, standardized methods are needed for video image compression due to its high-bandwidth requirements. Microsoft and other PC software and hardware manufacturers are developing a standard for still and full-motion video compression for Microsoft Windows. A standard is also being developed for X-Windows. In the future, an emerging technology called wavelets promises to provide up to 100 times compression with little data loss.

Data compression technology may be built into vertical or layered products, or may be purchased as libraries that can be incorporated into custom software. Software data compression provides flexibility but most real-time systems require hardware support for speed.

SOURCE: Space Station Ground Processing Study

B.29 Emissivity/Reflectivity Sensors

Emissivity readings at KSC are taken with a Gier Dunkle DB-100. The DB-100 probe is large and unwieldy (a 6-inch-diameter cylinder, about 10 inches long), with no place to get a good grip. It is hard-wired, via a 5-foot cable, to a large, heavy readout unit weighing about 50 pounds. Technicians often have trouble getting a tight fit to the blanket. Often, several readings must be taken to get an accurate value. Calibration of the emissometer is arduous using locally created samples of known emissivity. Often, the DB-100 cannot be calibrated and must be repaired, causing schedule slips.

The DB-100 uses a mechanism that will be difficult to miniaturize. However, there are many simple sensors which can take emissivity readings but which require sophisticated computer processing to produce an accurate value. There is no off-the-shelf product that can be substituted.

SOURCE: Space Station Ground Processing Study

B.30 Expert Systems

Expert systems provide the means to automate, using a computer, the decision-making process of an individual who is skillful at performing an operation. Expert systems were the subject of considerable interest a few years ago but have matured into a quieter state of development. The limits of robust system designs are now well known and these systems are in wide use but are embedded in products where they cannot directly be seen by the user.

Ongoing research is being conducted into artificial intelligence to expand the boundaries of these systems. Most developments start with a shell which is customized for the application, and expert knowledge is added via a process called knowledge engineering. NASA has several shells available to it at no cost or low cost. Commercial shells are also readily available. Programming requires a moderate degree of skill and specialized training. For simple applications, the programming is straightforward.

SOURCE: Space Station Ground Processing Study

B.31 Fiber-optic Data Communication

Both payload to orbiter interfaces and orbiter to pad interfaces involve numerous, complex, wire bundles and harnesses. The maintenance and testing of a massive number of individual connectors is costly, time consuming, and prone to error. The use of fiber-optic data communication cables would relieve this effort. A few optic-fiber cables, perhaps in a single harness, could be used to carry all data between a payload and the orbiter. To accomplish this obviously all signals currently transmitted in analog form would have to be digitized via signal conditioners and converters. The key to implementation is the testing and space-qualifying of fiber cabling and connectors.

SOURCE: STS Interview Database

B.32 Fluid Purity Systems

A flash evaporator device called the Solvent Purity Meter is presently being used for shuttle processing. This machine must be updated or a commercial equivalent must be found for payload processing. However, it is not an off-the-shelf product. A company called Virtis developed this device 20 years ago with NASA's help to comply with KSC Specification 123, Level 300a type standard of cleanliness. Virtis made only four of the machines, three of which were sold to KSC. One machine is still functioning. While it is no longer being manufactured, Virtis can construct duplicates for $12,000 each. However, this machine is not transportable and cannot be used to detect lubricants such as Krytox.

SOURCE: Space Station Ground Processing Study

B.33 High-Density Storage

Manual high-density storage facilities have been available for a long time. A high-density storage facility uses a conveyor to directly access articles from storage instead of having people get the articles themselves, removing the area required for human access. In the last 10 years, computers have been coupled to the high-density storage facilities to manage inventory and to automate handling functions. Commercial systems are now readily available and are already in use at KSC. Mechanisms for handling items are still in development, particularly robotic pick-and-place devices. The software for driving the storage conveyers is mature but the man-machine (human factors) interface and the interface to other work control systems is an area of new development.

High-density storage facilities must be carefully designed by experienced contractors for the characteristics of the items that the system must handle and for the human interface. Software for these systems must be modified to interface with the other work control systems.

SOURCE: Space Station Ground Processing Study

B.34 High-Level Programming Environments

Specialized high-level programming tools can help implement software applications. The best of these environments or tools has a point-and-click interface which can be used to edit forms or draw on screens the information needed to generate the program. These tools should present material in a context relevant to the domain of the problem. High-level programming environments have been shown to yield substantial reductions in cost. The most common examples are fourth-generation languages, or 4GLs, for database development and PC application development tools. Other examples include computer-based training authoring systems, programmable logic controller development environments, and multimedia development kits.

The greatest productivity gains are found in systems tailored to their use. However, highly tailored systems may have a short life span. These tools generally contain a WYSIWYG (what you see is what you get) editor, debugging tools, libraries, and testing tools. Advanced systems may have features that support team-based development such as data dictionaries and locking. In some areas such as database development, high-level programming environments are readily available from commercial sources. Several systems have been created by NASA for developing graphic user interfaces. Otherwise, tailored environments may be constructed by programming and integrating commercially available subsystems.

SOURCE: Space Station Ground Processing Study

B.35 Laser Ranging and Measurement

Laser distance measurement technologies also include scanning, illumination, and structured light, as well as ranging measurements. Measurements may be made with or without targets. Target-oriented laser distance measurement is a well-developed field, yielding higher accuracy than any other method over similar ranges. Products are available from a number of commercial sources. Proximity sensor or sensors to range from a surface are available. Laser tracking systems are usually purchased as subsystems that must be integrated into applications.

SOURCE: Space Station Ground Processing Study

B.36 Machine Vision and Automated Inspection

Machine vision utilizes optical sensors and computers to make decisions about real-world objects. This has proven to be a very difficult research and development area. There are commercial products which work in highly structured situations but they require specialists for implementation. Usually, vision systems inspect items that have known geometries or surfaces to find flaws. Positioning and lighting must be carefully controlled to get good results. Vision systems are widely used for inspection in industry because, while these system do not give perfect results, they are generally far more accurate than people because people get rapidly fatigued doing continuous inspection tasks. Machine vision is also used for positioning, alignment, and measurement.

SOURCE: Space Station Ground Processing Study

B.37 Model-Based Reasoning System

Model-based systems use a rich representation to control the operation of software applications. This has been formalized into the model-view-controller methodology which originated with the Smalltalk language. In this methodology, the model acts as the unifying data structure and can be viewed in several ways by parts of an application or by several applications. The software application operates on the model controlling the data changes. The model-view-controller methodology produces more flexible software, permitting cost-effective development of more complex systems. Most commercial object-oriented development environments support this approach.

SOURCE: Space Station Ground Processing Study

B.38 Noncontact Digitization

Noncontact digitization is the capture of a three-dimensional representation of the surface of an object without touching the object to measure it.. Various methods include stereo photogrammetry, laser scanning, and structured light. Use of lasers as a substitute for photogrammetry is a developing area and is likely to be the preferred approach for new systems. Automatix has developed a scanning system that provides 10 thousandths of an inch accuracy over a 36 inch field of view.

SOURCE: Space Station Ground Processing Study

B.39 Object-Oriented Programming

Object-oriented programming languages such as C++, LISP, and Smalltalk are gaining in popularity because it is simpler to build systems that need complex representations or promote code reuse. All of the languages have some kind of object-message paradigm that handles encapsulation, polymorphism, and inheritance. This method allows extremely complex software systems to be built in a modular fashion. The object models which form the documentation of a software system design are much easier to understand and follow than typical flow-chart methods. Most software systems share a number of common functions that can be handled by reusing and sharing objects. This provides programmers with the ability to provide platform-independent, easy-to-understand code that is reusable, thus reducing overall software development costs.

SOURCE: Space Station Ground Processing Study

B.40 Process Planning

Process planning helps design the flow of operations to meet specific parameters or requirements. The two basic kinds of process planners are generative and variant. Generative planners construct a flow based on an internal model of the underlying structure of the process. Usually, generative systems deal with low-level processes such as numerically controlled machines. Variant process planners take standard flows and aid the user in constructing tailored versions. Variant process planning is performed at KSC using tools such as Artemis to create processing flows for new payloads.

Process planning is presently more of an art than a science. The body of research in this area is weak, especially for assembly and test. There are few commercial tools available and most systems are constructed by adapting task planning and scheduling systems.

SOURCE: Space Station Ground Processing Study

B.41 Robotic Manipulators

A robotic manipulator is a device that can manipulate objects in three-dimensional space (position and orientation) in an automated, flexible manner. Most available manipulator systems are designed with a serial chain of jointed segments. However, other designs such as platform devices are also considered to be manipulators. Virtually all commercially available robotic arms are still simplistic devices that are almost identical in their functionality. This is adequate for highly repetitive large-volume tasks that are typical in factory production. However, the available arms are not able to perform the more dexterous tasks at KSC.

Nearly all commercial robot arms have six degrees of freedom or joint motions. Six joints are the minimum number required to change the position and orientation of a manipulated object. However, many difficult tasks must be performed in highly cluttered areas in which a six-degree-of-freedom arm cannot achieve the desired end-effector position while avoiding collisions between any of its links and some obstacle. In this case, a geometrically redundant system that has additional independent axes is required. For a given required end-effector position and orientation, a redundant system has an infinite number of ways its links can be configured, making it more likely that a collision-free configuration can be found.

The primary difficulty in implementing robotic systems for spacecraft operations has been the cost of custom-building arm segments with unique geometric dimensions and the cost of developing unique computer control systems. Standardized control systems that could be easily customized to include additional axes, user-developed interfaces, sensor feedback systems, and other items are needed to reduce these costs. Also, modular manipulator joints and link segments, which could be easily assembled in different configurations with various dimensions, would save extensive design and fabrication costs. A robot system which requires a reasonable cost to develop could provide highly improved operations for certain tasks.

SOURCE: Space Station Ground Processing Study

B.42 Virtual Instrumentation

Virtual instrumentation displays gauges or dials on a computer screen instead of using physical devices. This approach is more cost-effective when computers are available since the software is less expensive than the physical devices and does not need calibration (though the sensors and data acquisition devices do). Virtual instrumentation packages simplify the construction of displays, and the displays are easy for the user to read. Virtual instruments may be used in a networked system such as the Test and Checkout Management System (TCMS) or in data acquisition systems constructed using standard PCs.

SOURCE: Space Station Ground Processing Study

B.43 Work Control Systems

Work control systems are groups of applications used to manage ongoing operations. Typical applications include materials management, configuration management, scheduling, and work tracking. These systems generally integrate custom database applications and purchased software. There are work control architectures which have been defined by several computer systems companies and there are a number of commercial packages which bundle work control applications. However, for large enterprises such as payload processing, few turnkey systems provide all the needed services; instead, a vendor provides a shell that is modified for the enterprise.

SOURCE: Space Station Ground Processing Study

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Rex Shaffer

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The purpose of this research is to provide innovative and creative approaches to assess the impact to the Kennedy Space Center and other launch sites for a range of candidate manned and unmanned space transportation systems. The general scope of the research includes the engineering activities, analyses, and evaluations defined in the four tasks below.

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