AN INTERACTIVE COMPUTER APPROACH TO PERFORMING RESOURCE ANALYSIS FOR A MULTI-RESOURCE/MULTI-PROJECT PROBLEM

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ABSTRACT

Current inventory planning in the National Aeronautics and Space Administration (NASA) has required the development of efficient methods to project resource procurements. This paper addresses a specific type of resource analysis and its implementation in an interactive computer system environment. This type of analysis is described as a multi-resource/multi-project (MR/MP) model. The emphasis of this article is towards two aspects of the solution process. The first involves an efficient approach for inputting the problem characteristics into the computer data base. The second addresses the scheduling procedure and analysis used for minimizing resources. Both represent important parts of the end-to-end resource utilization problem. Solution is accomplished with an interactive man/machine system.

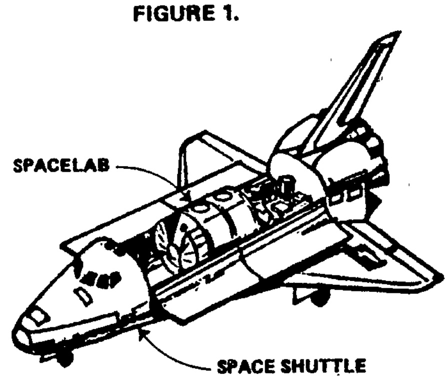
Descriptions of the data base operations and example outputs from the program are presented. A comparison of the operations time in solving the MR/MP problem with interactive front-end processing over end-to-end batch runs is given.

INTRODUCTION

Reduction of federal spending and projected increases in the number of payload flights for the United States Space Program have required an increasing need in new planning techniques and supporting computer tools. One important category of these tools involves optimization of resources and costs for space transportation and payload systems. These tools must be developed to give not only optimum or acceptable results, but also provide the solution within a reasonable time frame.

Heavy emphasis on cost effective utilization of resources has caused NASA program planners to look at the impact of various independent variables that affect procurement buying. Specifically, the category of resource planning described in this paper deals with Spacelab inventory procurement analysis. Spacelab is a joint payload project between NASA and the European Space Agency and will be flown aboard the Space Shuttle starting in 1980. See Figure 1.

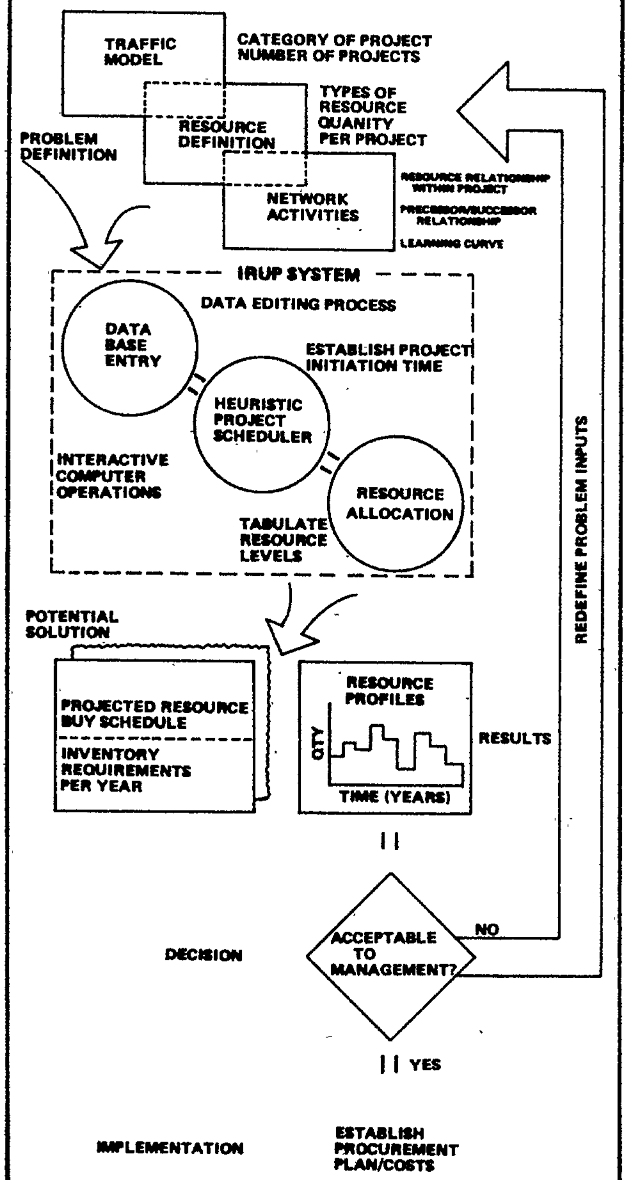
FIGURE 1.



On many missions, a special self-contained laboratory or core segment will provide payload specialists a shirt-sleeve environment to operate various experiments. The Spacelab program will require the reuse of many different facilities, flight hardware, and support equipment over the next decade. These resources will be acquired in the early phases of the program; therefore, a good method of projecting realistic quantities was needed. In order to respond rapidly to the various procurement planning exercises, a system was built that could perform resource analysis in a quick and efficient matter. This system is known as the Interactive Resource Utilization Program (IRUP). The IRUP system is a tool providing management with a solution for sizing resource procurements. Figure 2 illustrates the relationship of IRUP to the overall procurement planning process. This paper explains the specific resource problem and the features of IRUP used in its solution. These features include data base entry, project scheduling, and resource allocation.

RESOURCE ANALYSIS AND PROCUREMENT PLANNING OVERVIEW

FIGURE 2.



PROBLEM DEFINITION

Spacelab procurement planning considers the allocation of more than 25 major resources. These resources include flight hardware (see Figure 3) such as core segments, pallets, racks, experiment equipment, and other miscellaneous elements. Other resources are various facilities such as assembly and integration work-stands. Support equipment resources include simulators, automatic test equipment, and mechanical gear. The cost range varies from thousands to millions of dollars per item. The quantities of resources are projected over a 12-year time period (1980 to 1991). These procurement requirements must be established in the initial phase of the Spacelab program, since manufacturing and funding plans are being presently defined.

SPACELAB FLIGHT HARDWARE

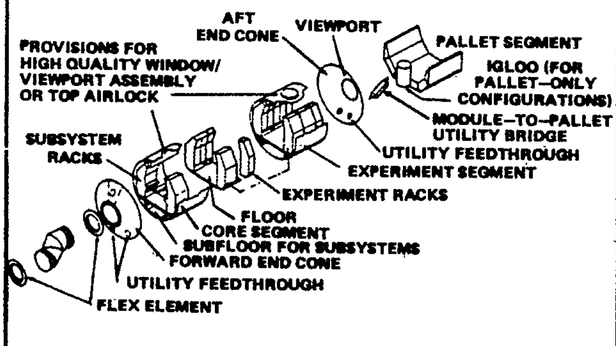


FIGURE 3.

There are three sets of variables that influence the quantities of items to be bought. These are: the payload traffic model; payload dependent resource configurations; and activity networks. Each will be described as follows.

The Spacelab payload traffic model consists of a specified number of missions to be flown each year from 1980 to 1991. The model contains the type payload and its mission objective (i.e., life science, astronomy, space manufacturing). As many as 50 types of payloads have been defined. Current models indicate the frequency of payloads to fly is from 2 to 29 per year. Over 200 payloads are scheduled during the 12-year period. Many traffic models have been proposed and are analyzed for their impact on resource levels.

Resource configuration requirements for each payload are determined by the type of mission to be flown. Each payload can take on a different configuration of flight hardware, thus affecting the resource requirements for each mission. As an example, payload #1 may require one core segment and no pallets, while payload #2 may use no core segments and five pallets. Payload #3 could require one core segment and one pallet. Therefore, a complement of resources is assigned to a mission. The configuration of each payload is determined by the category defined in the traffic model.

The third variable affecting inventory requirements is the activity network or operations timeline. Each timeline is a set of mission/payload dependent activities defined by a precedence network. A Gantt chart of the top level activities of such a network is shown in Figure 4. Each payload can have its own set of prelaunch, flight, and post-launch operations. Resources enter (seize) and leave (release) the flow at various stages in the timeline. For purposes of Spacelab inventory planning only six different networks were established, each containing 40 to 50 activities. Within any single network, activity start and stop times are considered fixed events relative to a launch time and do not shift within a mission. Time values are defined in working and/or calendar hours. For most studies a learning curve was applied to the first 20 missions. An 80 percent reduction in activity time was applied from one mission to the next. Certain operations such as transportation and flight time were not affected by learning.

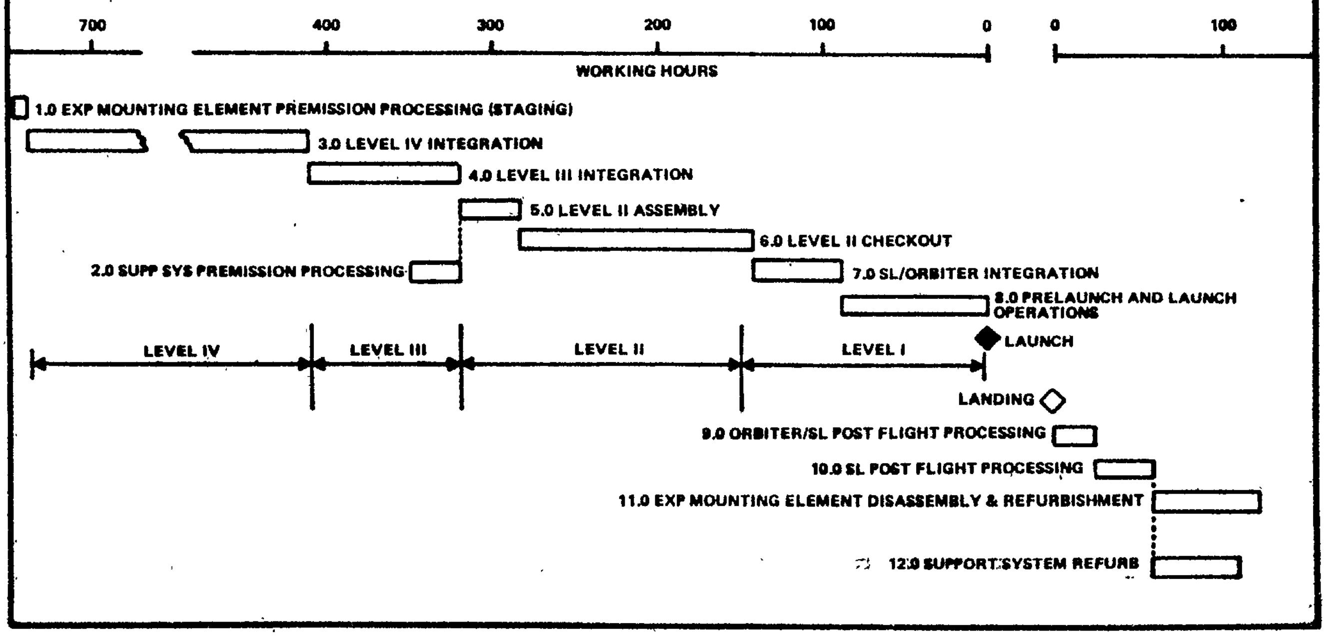
A summary of characteristics sizing for a typical problem is shown in Table 1. The information content in single data set represents a factorial combination of these characteristics and their supporting attributes. This set translates into 3000 to 4000 data base entries for each new study.

SIZING CHARACTERISTICS FOR A TYPICAL PROBLEM
TABLE 1

PROBLEM VARIABLE	SIZE
TOTAL NUMBER OF PAYLOADS TO BE SCHEDULED	>200
NUMBER OF PAYLOAD CONFIGURATIONS	50
NUMBER OF INDEPENDENT ACTIVITY NETWORKS	5
NUMBER OF ACTIVITIES PER NETWORK	40
NUMBER OF RESOURCES	25
NUMBER OF RESOURCE LEVELS	0→80

The objective involved in determining Spacelab procurement inventory is centered around the minimization of total resource costs during each year of the traffic model. In other words, scheduling of resource usage to minimum levels would optimize procurement buys. For a given set of conditions (traffic model, activity networks, and resource configurations) a suitable schedule of launch dates had to be calculated that would keep resource levels at a minimum. A review of the literature (1)(2)(3)(7) did not lead to a mathematical technique which would produce an "optimal" solution within a reasonable computational time. However, classification of a category of heuristics that leads to a "good" solution was found. This category provides methods for solving the unconstrained, multi-resource/multi-project (MR/MP) problem. A simple computation solution was selected.

OPERATIONAL PHASE TIMELINE ALLOCATION
FIGURE 4.



Due to extreme size of the data base and the lack of any closed form solution to the problem, two separate issues had to be addressed before a practical system could be developed for performing a computer analysis. The first describes a method for inputting the masses of data used for describing the resource model. The second discusses the design of a heuristic procedure for scheduling payload operations with minimum resource allocation. The following sections describe the IRUP system and explain its major features.

IRUP SYSTEM DESCRIPTION

The IRUP system was built to satisfy the major functions as shown in Figure 2. These functions have unique requirements that utilize special features of two different computers, the PDP 11/70 and Univac 1108. Various trade studies were performed that led to the selection of the PDP for performing the data base entry functions and the Univac for scheduling and resource allocation. Major selection factors influenced the system configuration. Key characteristics are grouped by computer.

The 11/70 system provides the following capabilities in support of IRUP data base operations:

- 300,000 baud rate communication line to CRT user terminal
- Continuous on-line availability of data base files
- Display-processing software
- User terminal-tablet and hand data point cursor
- Direct communication interface to the Univac 1108 system for data base transfer

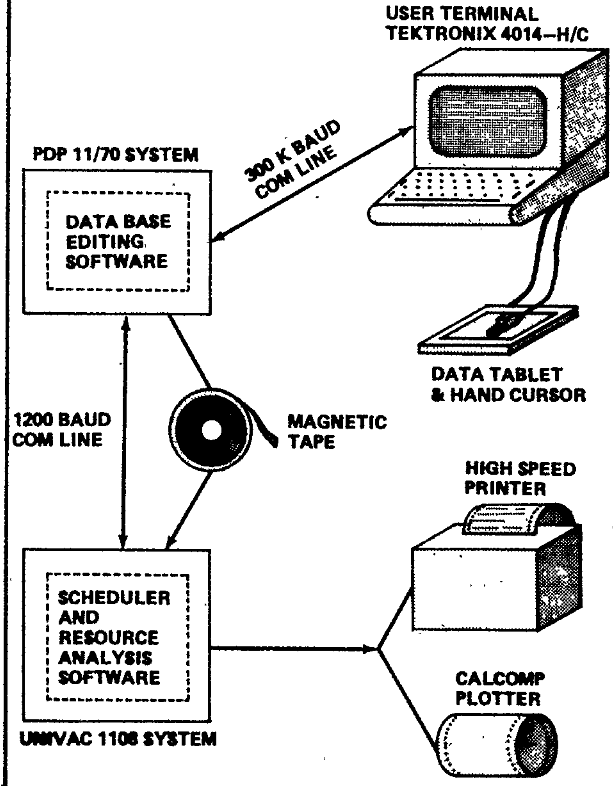
The key features of the 1108 system for supporting the resource analysis functions are:

- 65K of 36 bit memory per user
- Fast CPU (processing speed of 5 to 1 over the PDP computer system)
- Availability of various plotting devices

Both systems give the IRUP user the advantages of high-speed, interactive data editing and fast computational processing. An overview of the hardware and software is shown in Figure 5.

IRUP SYSTEM OVERVIEW

FIGURE 5



In addition to the PDP computer, other basic hardware includes a Tektronix 4014 storage display CRT, Summagraphics data tablet and cursor, a 40 million word hard disc, and two small, one million word removal disc/packs. Two different 1108 computers are available to the IRUP user. Both 1108's have a full complement of main frame peripheral devices. Resource profiles can be plotted on either a 12-inch Calcomp or a FR-80 (digital to microfiche). Computer (1108) program execution can be initiated interactively in both demand or batch mode. The batch mode is beneficial when the IRUP analyst wants to execute many runs without remaining at the terminal for output results.

Communication between computers is handled over a 1200 baud voice equivalent line. Dial-up of the 1108 is automatically handled through IRUP communication software resident in the PDP. Due to the low transmission rate between computers, transfer of one data set takes from six to eight minutes. This situation will be alleviated with the future installation of a 9600 baud line. Magnetic tape capability serves as an alternate mode for transferring data.

DATA BASE ENTRY

Data base entry for most resource planning/ scheduling systems becomes a major and time consuming task. Experience and investigation of specialized languages such as GASP (4), GPSS (6), and PLANS (5) have not simplified the translation of model definition attributes into computer type format. Much time is expended in sitting at a terminal keyboard or writing down problem characteristics on key punch forms. The conversion of descriptive attributes into a computer format becomes of great concern when the amount of data input requires thousands of entries for a single resource allocation study. The time for data base entry can overshadow any time savings gained through an efficient computational solution.

In order to reduce data entry time, IRUP contains an interactive, front-end processor for performing file editing and management services. The processor allows the user to concentrate on data definition, thus eliminating the knowledge of special formatting and bookkeeping functions. The system is based on a menu/display oriented design containing the following features:

- Hierarchy of Functional Levels
- Tablet/Hand Cursor/Keyboard Directed Inputs
- Customized Displays
- Standard Display Operations
- User Assisted Instructions
- Simple/Non-Rigid Input Format
- User-Transparent File Management Operations

A hierarchy of function levels has been included in the IRUP system that permits the user to branch down to any level of input definition required. A sample of the top level functions as it appears on the terminal screen is illustrated in Figure 6A. Figure 6B represents the next level for INPUT DATA function. All displays are in instructional or data table format. A unique feature[1] of the system permits branching

[1]Display control software/hardware developed by M&S Computing, Inc.

through the set of pre-stored library of displays in a fast and simple manner. Terminal projection of the displays is accomplished over a 300K baud line onto a 19 inch CRT. The high rate of data transfer along with the display tree concept provide the same flexibility as flipping through the pages of a book.

IRUP FUNCTIONAL HIERACHY
FIGURE 6A

IRUP MAIN MENU

INPUT DATA	+
SELECT OUTPUT	•
READY IRUP FOR EXECUTION	•
SAVE INPUT FILE	•
TERMINATE IRUP	•
HELP	•

FIGURE 6B
DATA ELEMENT MENU

INPUT THE NAME OF THE DATA ELEMENT YOU DESIRE FOR EACH OF THE NINE (9) TYPE ELEMENTS THAT FOLLOW.

DATA ELEMENT NUMBER	DESCRIPTION	DATA ELEMENT NAME
1	MISCELLANEOUS DATA	------------
2	GENERAL EVENT DATA	------------
3	EVENT FREQUENCY	------------
4	ACTIVITY DESCRIPTION	------------
5	ACTIVITY RELATIONSHIP	------------
6	RESOURCE REQUIREMENTS	RR_GA------
7	RESOURCE UTILIZATION	------------
8	WORKSTATION REQUIREMENTS	------------
9	WORKSTATION UTILIZATION	------------

INPUT FOR THIS DISPLAY COMPLETE	•
HELP	•

All inputs to the data base are handled through the use of a tablet/hand-held cursor, and a standard ASCII keyboard. Three modes of user-to-terminal inputs are accomplished through the pen option, compose field entry, and enter-data field operation. The pen option utilizes the cursor and tablet and allows the user to point to the desired function on the screen. Once the data button on the cursor is depressed, the selected function is implemented. The compose field allows keyboard entry of data in place at a fixed position on the screen. Position is selected by advancing the screen alpha cursor to the designated input field by depressing the RETURN key. The enter data field uses a combination of the hand cursor and keyboard. The operator types the data in the lower left-hand portion of the screen and selects the position of placement with the cursor. The data appears on the screen at the coordinates of the cursor cross hair. With these three modes, the user can update, add to, or delete any data values on the screen in just a matter of seconds. Operation is similar to using a pencil, pad, and eraser. Examples of IRUP input modes are shown on Figures 6A, 6B and 7.

All displays in IRUP are customized around the type of data to be entered. The user enters information into a data table format similar to the layout of the actual engineering data. Nine separate categories of data elements (Figure 6B) were designed. These constitute a set composed of a traffic model, resource requirements, and activity network (timeline) descriptions. An example portion of the payload resource requirements display element is shown in Figure 7. In most cases, the computer displays serve as documentation of the input data through use of a hard copy device.

An important feature in the design of the IRUP processor is the standardization of display operations. Each data display as in Figure 7 contains a set of seven functions. The functions include: Add/modify data; Delete data; Update display; Help; Go to next page; Return to prior page; and Operations on this data element complete. Most of these functions are self-explanatory. The "Help" option gives immediate access to dedicated instructions and data definitions. This allows for the part of the user's manual to be built into the IRUP system. No column justification is required for entry of individual data values, therefore removing the rigid formatting structure inherent in conventional computer language inputs.

File management operation during an input session is transparent to the user. The system automatically allocates working files and allows the user the option of saving all data elements that have been created or modified during the data editing session. The data element to be saved can be named any 12 character or less title with no restrictions on special characters or imbeded blanks. A single set of all nine IRUP elements may be defined as a collective group name. This capability allows instant recall of a single data case for future terminal sessions.

IRUP PAYLOAD REQUIREMENTS DISPLAY
FIGURE 7

DATA ELEMENT 6A - RESOURCE REQUIREMENTS

RESOURCE ID / ACTUAL CONFIG	CORE SEGMT	EXP SEGMT	AFT END CN	TUNNEL	PALLETS	RACKS	IGLOO	ELEV I EQ	WLEV I EQ	NUMBER ACT
SL-1	1	1	1	1	1	16		1		1
MUB1					5		1	1		1
MB17	1	1	1	1	1	16		1		1
MB14	1	1	1	1	1	16		1		1
MB12	1		1	1	3	6		1		1
MB22	1	1	1	1	1	16		1		1
MB23	1	1	1	1	1	16		1		1
MB32	1	1	1	1	1	16		1		1
MB37	1		1	1	3	6		1		1
MB34	1		1	1	3	6		1		1
MUB4	1		1	1	3	6		1		1
S117					5		1	1		1
S27W					5		1		1	1
S24W					5		1		1	1
S37W					5		1		1	1
S34W					5		1		1	1
LS7E	1	1	1	1		16		1		1
LS4E	1	1	1	1		16		1		1
ATL7	1		1	1	2	6		1		1
ATL4	1		1	1	2	6		1		1
PA7E					5		1	1		1
AS7E					5		1	1		1
AS4E					5		1	1		1
AP7W	1		1	1	3	6			1	1
AP4W	1		1	1	3	6			1	1
EN4E	1		1	1	3	6		1		1
EN7W	1		1	1	3	6			1	1
EN4W	1		1	1	3	6			1	1

ENTER DATA: ____

ADD/MODIFY DATA ●   GO TO NEXT PAGE ●
DELETE DATA ●   RETURN TO PRIOR PAGE ●
UPDATE DISPLAY ●   OPERATIONS ON THIS DATA ELEMENT COMPLETE ●
HELP ●

Upon completion of data base entry operation, a comprehensive error check is performed. The check tests for interdependency relationships between the data elements and eliminates a wasted computer resource analysis run due to missing or non-logical input data.

Experience to date has shown a great reduction in data base entry operations with an interactive input processor. An original batch version of the resource program required problem entries to be made on 16 different card formats containing 70 individual data fields. This awkward method required the program analyst to be quite familiar with the input structure. The worst aspect of the batch method was validation of the data set. It was sometimes possible for an incorrect data entry to go unnoticed for months. An example of this was a 7-day mission duration that was entered 7_ or 7 Ø in a right justified field.

Table 2 shows the time comparison between interactive and batch operations. The greatest improvement has been in reduction of the data entry time for new studies.

COMPARISON OF INTERACTIVE VS BATCH TIMES FOR RESOURCE ANALYSIS

TABLE 2

OPERATION / METHOD	INTERACTIVE	BATCH
NEW DATA SET ENTRY	4–5 HOURS	16–20 HOURS
TYPICAL UPDATE TO EXISTING DATA SET	<1 HOUR	2 – 3 HOURS
COMPUTER RESULTS/OUTPUT AVAILABILITY	5 – 12 MINUTES	8 – 24 HOURS
INPUT VERIFICATION/DOCUMENTATION	1 HOUR	8 HOURS

PROJECT SCHEDULER

Producing a totally automated payload schedule with minimum resource levels is most difficult due to the many variables involved. The large combination of events (200 payloads over 100,000 time intervals) and the lack of a single criterion for optimality which can be easily handled by mathematical programming has resulted in the application of heuristic scheduling algorithms. Heuristics are usually tailored to specific problem characteristics and result in a good or acceptable solution to the scheduling problem. The heuristic used in IRUP generates a set of potential payload launch dates. The time of all other resource activities is established from these dates. The overlapping of common resource activities through time causes increases in resource levels. The idea behind resource minimization is the separation of each mission or project so that a resource requirement from one flight to the next does not conflict. However, as flight frequencies become greater, resource overlap increases causing resource levels to go up. The basis of the IRUP scheduling technique for Spacelab payloads takes advantage of the fact that only four costly resources are the major drivers in establishing total procurement costs. Other resources do not strongly affect procurement decisions. Observation of this fact led to the IRUP scheduling algorithm.

The foundation of the heuristic is based on assigning a uniform distribution of hardware mix throughout the traffic model year. The categories of hardware mix are assigned by the configuration of major flight hardware used on a mission. Seven categories were selected and ranked according to the type of resources required. The configuration categories and corresponding letter code are given in Table 3.

TABLE 3

E – CORE SEGMENT, EXPERIMENT SEGMENT, AND PALLETS
M – CORE SEGMENT AND EXPERIMENT SEGMENT
C – CORE SEGMENT AND PALLET
A – 3, 4, OR 5 PALLETS WITH IPS
P – 2 OR 3 PALLETS ONLY
U – UNIQUE-RESERVED FOR SPECIAL CONFIGURATIONS
S – 1 PALLET ONLY

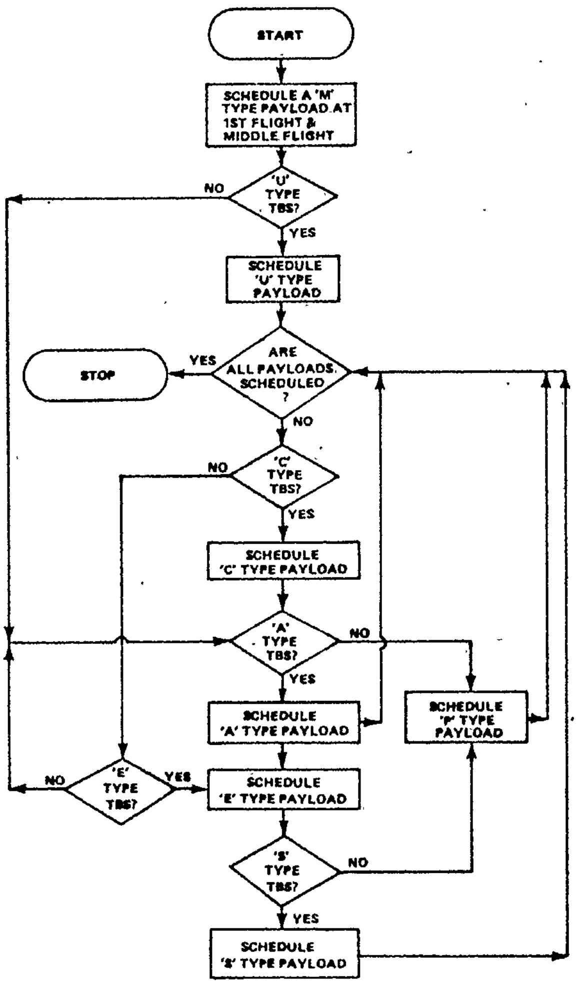
Each payload in the traffic model is grouped into one of these categories. The order in which a payload candidate is chosen for scheduling is handled through a maximum/minimum resource assignment scheme. This logic is illustrated in Figure 8. The method basically selects a heavy resource mission (category E, M, or C) followed by a nonconflicting minor resource mission (category S, P, or A). The project scheduler continues to work its way down the list of flights to be scheduled by alternating between a core segment type configuration and pallet-only mission. Individual selection within a category is made randomly or through a prespecified order. Actual time of launch is calculated by taking the number of calendar hours in a year and dividing it by the flight frequency. Payloads are then placed on the schedule according to the algorithm order. An example of the payload scheduling for a 12-flight-a-year traffic model is illustrated in Figure 9.

Experience with this simple scheduler has resulted in realistic resource profiles. Additional refinement in the minimization process can be gained by shifting the time of each mission relative to the others and then checking the resource histogram for the most cost-effective launch date. However, the iteration method uses a large amount of computer processing time without a significant improvement in resource levels. Comparison of results between IRUP scheduler and the string of pearls heuristic (7) shows only small differences in minimum hardware quantites. Computer execution for the IRUP scheduler averaged about five to ten seconds for a schedule of 230 payloads.

In addition to automatic scheduling, the IRUP system allows the user to input his own event times if predetermined launch dates are chosen. Also, alternate scheduling routines using different priority schemes can be integrated into the IRUP system and easily selected upon execution.

SCHEDULING ALGORITHM LOGIC

FIGURE 8.



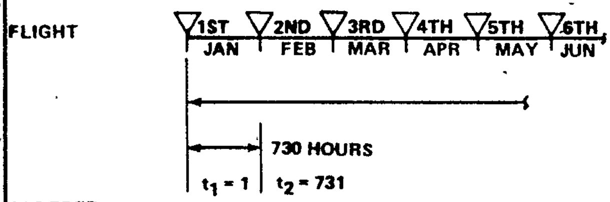
EXAMPLE OF SCHEDULING ALGORITHM

FIGURE 9

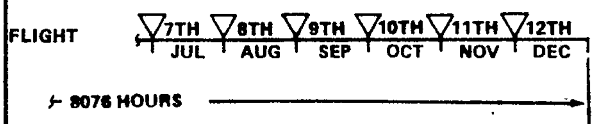
F = 12 FLIGHTS/YEAR $\Delta t = \frac{8760 \text{ HOURS/YEAR}}{12 \text{ FLTS/YEAR}} = 730 \frac{\text{HOURS}}{\text{FLT}}$

PAYLOAD	FREQ.	CS	ES	PALLET	IPS	CATEGORY
		CONFIGURATION				
N1AK	1	1	0	3	0	C
S2A7	1	1	1	2	0	E
O1AK	1	1	1	2	1	E
L2A7	2	1	1	0	0	M
MU27	1	0	0	4	2	U
S1A7	1	1	1	1	0	E
P6A7	1	0	0	3	0	P
A001	1	0	0	3	3	A
SP01	1	0	0	4	3	A
S1B7	1	0	0	1	0	S
P7A7	1	1	0	3	0	C

ORDER SCHEDULED	1	3	4	5	6	7
PAYLOAD	L2A7	MU27	N1AK	A001	S2A7	S1B7



ORDERED SCHEDULED	2	8	9	10	11	12
PAYLOAD	L2A7	SP01	P7A7	P6A7	01AK	S1A7



RESOURCE ALLOCATION

After a schedule of payloads and corresponding launch dates has been generated, the IRUP system performs resource allocation. The program determines an exact start and finish time for each event over the specified analysis period. Detailed resource requirements profiles are then computed containing the seize and release time for each individual resource. An output module creates various reports and histogram plots supporting engineering evaluation and analysis.

The Resource Utilization Summary and Resource Requirement Summary Reports (Figures 10 and 11), contain resource information used by procurement planning personnel. Detailed time phased resource profiles (Figure 12) aid the analyst in graphically identifying time periods of heavy resource utilization. Figure 10 illustrates a statistical analysis of detailed pallet profiles for the years 1990 and 1991. The data is tabulated by time period and corresponding utilization-level attributes such as total time, maximum time, and number of occurrences are printed. Figure 11 shows yearly tabulations of PEAK and BUY levels for three different resources-core segment, pallets, and racks. Average utilization per resource level is also given. The PEAK values are the maximum quantity projected over a given time period. The BUY row represents a proposed procurement level as tabulated by analyst specified criteria. For most studies, the amount of equipment required to meet 95 percent availability was used. This criteria represents a quantative constraint for reducing maximum procurement quantities. The 95 percent criteria has the limited effect of performing resource smoothing; thus being a subjective way of estimating that five percent of the schedule could be manipulated to reduce peak resource requirements. It is safe to assume that a small amount of rescheduling is not unreasonable, since unmodeled variables such as overtime and activity slack could alleviate certain resource conflicts. Additionally, most program managers would be reluctant to base procurement buys on low utilization of peak resource projections.

Resource allocation analysis also allows the evaluator to access any violated constraints, such as unavailability of a certain resource quantity before a specified online date. It is possible for the user to make manual reassignments of the launch dates so that most or all conflicts are resolved. Thus the system can be used iteratively to produce totally acceptable resource levels.

FIGURE 10

RESOURCE UTILIZATION SUMMARY PROFILES

PALLET SEGMENT

RES PALLETS

FOR ALL ACTIVITIES

TIME PERIOD FROM (19000000) TO (19008700)

QUANT	TOTAL TIME	PERCENT	CUMULATIVE	MAX TIME	NO OF TIMES
9	35	0	.4	35	1
11	101	1	1.6	76	2
14	1216	14	15.4	480	4
15	644	7	22.8	234	4
16	634	7	30.0	215	6
17	526	6	36.0	203	4
18	170	2	38.0	170	1
19	1228	14	52.0	521	6
20	816	9	61.3	234	6
21	1054	12	73.3	384	4
22	631	7	80.5	208	4
23	632	7	87.8	320	3
24	480	5	93.2	250	2
25	340	4	97.1	217	2
27	253	3	100.0	130	2

TIME PERIOD FROM (19010000) TO (19018700)

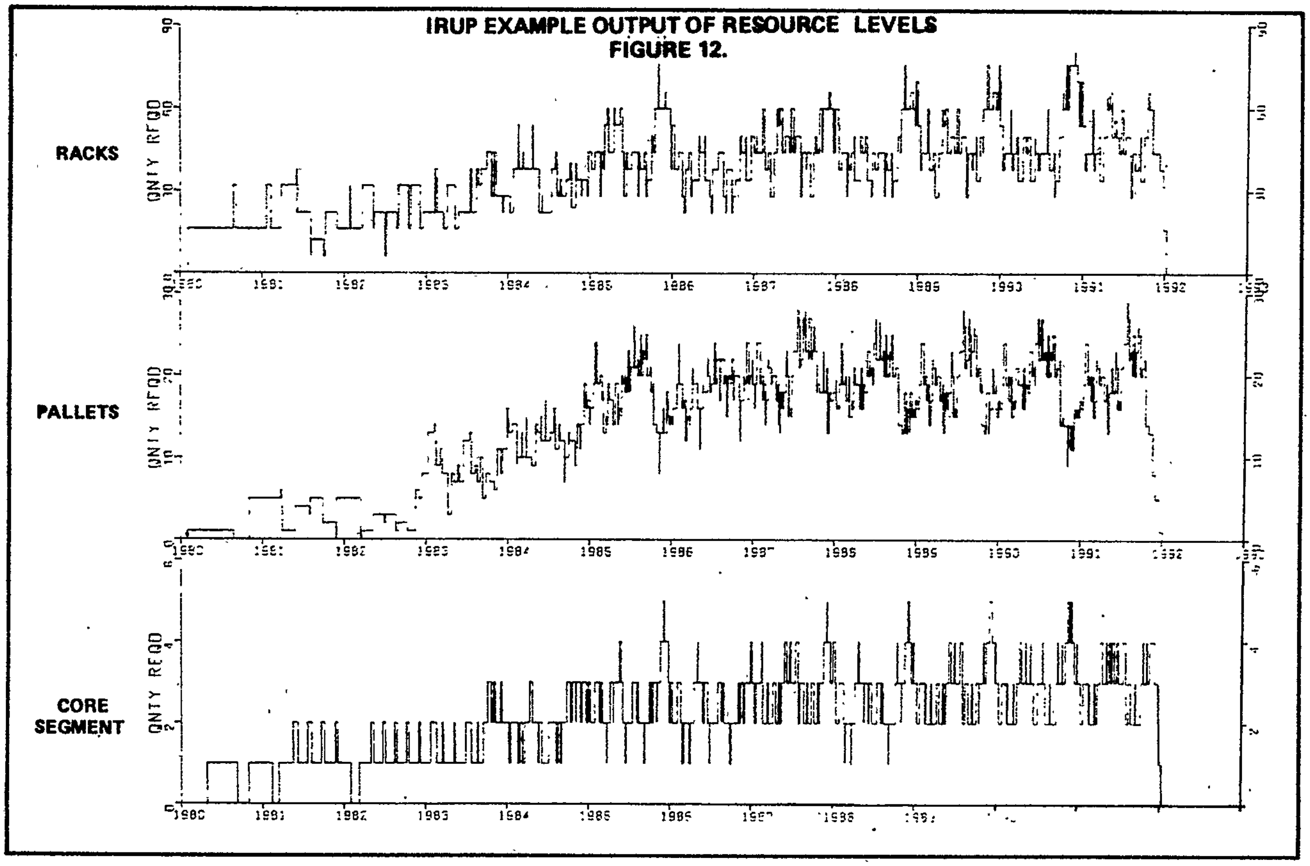
QUANT	TOTAL TIME	PERCENT	CUMULATIVE	MAX TIME	NO OF TIMES
1	189	2	2.2	189	1
2	76	1	3.0	76	1
5	382	4	7.4	308	1
8	343	4	11.3	343	1
13	533	6	17.4	447	2
14	449	5	22.5	343	2
15	150	2	24.2	150	1
16	300	4	27.8	143	3
17	852	10	37.5	265	5
18	450	5	42.6	232	2
19	584	7	49.3	152	6
20	1030	12	61.0	350	6
21	1170	13	74.4	312	5
22	300	4	77.9	150	3
23	528	6	83.9	263	3
24	728	8	92.2	406	2
25	476	5	97.7	281	2
26	8	0	97.8	8	1
27	115	1	99.1	115	1
29	80	1	100.0	80	1

FIGURE 11

REPORT 8 IRUP EXAMPLE OUTPUT OF RESOURCE PROCUREMENT LEVELS RUN TIME 082777 130350

RESOURCE REQUIREMENTS SUMMARY REPORT OPTIONS

RES/WORK STA	OPTION		YEARHOUR 19800000 19808760	YEARHOUR 19810000 19818760	YEARHOUR 19820000 19828760	YEARHOUR 19830000 19838760	YEARHOUR 19840000 19848760	YEARHOUR 19850000 19858760	YEARHOUR 19860000 19868760	YEARHOUR 19870000 19878760	YEARHOUR 19880000 19888760	YEARHOUR 19890000 19898760	YEARHOUR 19900000 19908760	YEARHOUR 19910000 19918760
CORE SEGMT	PEAK	QNT	1	2	2	3	3	5	4	5	5	5	5	4
		UTL	54.3 %	55.5 %	52.4 %	52.1 %	68.7 %	53.2 %	59.9 %	57.0 %	55.1 %	57.7 %	57.4 %	74.0 %
	BUY	QNT	1	2	2	2	3	4	3	4	4	4	4	4
		UTL	54.3 %	55.5 %	52.4 %	74.0 %	68.7 %	66.4 %	79.1 %	71.2 %	68.4 %	71.3 %	70.9 %	74.0 %
PALLETS	PEAK	QNT	5	6	8	16	19	26	24	28	27	28	27	29
		UTL	28.0 %	61.0 %	39.4 %	55.8 %	64.1 %	68.4 %	77.2 %	72.6 %	70.4 %	68.9 %	70.8 %	62.3 %
	BUY	QNT	5	5	5	13	14	22	22	25	23	24	24	24
		UTL	28.0 %	72.8 %	59.1 %	68.3 %	85.0 %	80.0 %	83.8 %	80.5 %	82.0 %	79.7 %	79.1 %	74.7 %
RACKS	PEAK	QNT	32	38	32	44	54	76	54	66	76	76	82	66
		UTL	46.7 %	55.6 %	74.8 %	63.1 %	60.5 %	61.8 %	70.6 %	73.2 %	60.1 %	64.5 %	59.9 %	70.8 %
	BUY	QNT	16	32	32	38	38	60	44	60	60	60	76	60
		UTL	90.5 %	65.8 %	74.8 %	71.7 %	84.6 %	78.1 %	85.1 %	80.3 %	76.8 %	80.3 %	64.6 %	77.3 %



IRUP EXAMPLE OUTPUT OF RESOURCE LEVELS
FIGURE 12.

CONCLUSION

The utilization of a computerized system for performing large project resource analysis can be a time consuming task. Two important aspects in the design of such systems must consider efficiency in data base entry operations and simplification of scheduling techniques. IRUP incorporates these features and provides a fast end-to-end solution to the procurement planning problem.

The next generation scheduling and planning systems within NASA will deal with a different set of problems. In particular, the emphasis will be on real time allocation of pooled resources. Inventory management of day-to-day, reusable resources will require new methods of interactive man/machine scheduling. The use of distributed processing and interactive man-in-the loop schedule heuristics will be part of these new systems.

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