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Study 2.5 Final Report DORCA Computer Program Analysis Report

Prepared by
ADVANCED VEHICLES SYSTEMS DIRECTORATE
Systems Planning Division

31 August 1972

Prepared for OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

Contract No. NASw-2301

Systems Engineering Operations
THE AEROSPACE CORPORATION

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DORCA COMPUTER PROGRAM

Analysis Report

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STUDY 2.5 FINAL REPORT
DORCA COMPUTER PROGRAM

ANALYSIS REPORT

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1. INTRODUCTION

During the latter phases of development of the pilot version of the DORCA computer program it became apparent that one of the major tasks for utilizing DORCA would be the task of performing traffic analyses of the "so called" automated satellite program. At that point in time, the emphasis on utilization/justification of the Shuttle was switching from manned exploration/exploitation of the moon and planets to a near-earth manned and unmanned program with periodic unmanned probes to most of the planets. This change in project (program) content necessitated an accompanying change in the primary operations mode to be considered using DORCA. The automated satellite program was basically predicated on the concept of ground-based vehicle operation, in which vehicles required to transport payloads from earth orbit to final destination, were delivered to and returned from earth orbit for each individual mission flown. Prior to this, the DORCA program had been geared to space-based vehicle operations with orbit-to-orbit vehicles operating beyond the range of the Shuttle. The orbit-to-orbit vehicles were assumed to be stored, fueled, and maintained in earth orbit until the end of useful life.

Furthermore, the vehicles utilized on the various segments (legs) of the mission trajectory were, for any given computer run, predetermined by the user. Only one vehicle could be generally assigned to service a specific leg. Any desire to deviate from the specified service had to be accomplished via a manual override in the input mission data stream. The effect and/or feasibility of utilizing other vehicles or groups of vehicles to service the various legs could be investigated only by making a series of computer runs. Results obtained from previous computer runs would be used to generate input data required for subsequent computer runs. Inherent in the analyses of the automated satellite program was the assumption that a number of vehicles were available to perform any or all of the missions within the satellite program. The objective was, of course, to select a vehicle or group of vehicles for performing all of the missions at the lowest possible cost. In order for the program to conform to the methodology being developed for the analysis of the satellite program, it was necessary to incorporate into the computer program, a vehicle selection routine and the capability to simulate ground-based vehicle operational modes.

2. BACKGROUND

While there existed a need for the DORCA computer program which could be operated with the same ground rules as those used in the analysis of the satellite programs, it was not thought that the DORCA program would actually be utilized in the conduct of the analyses being conducted or contemplated. Capture analyses were initially performed manually and the nature of the analyses seemed to dictate a continuation of the manual analyses. In much of the completed initial work, ground rules and guidelines were quite fluid and subject to frequent change; aspects which were not mechanized easily on the computer. Current analyses in this area are being conducted with much firmer ground rules, although some changes are still introduced in order to investigate new and/or modified analytical/operational approaches. With the advent of this more stable study base and the mechanization of other facets of the total analytical effort, provisions were incorporated into DORCA so that traffic analyses comparable to those obtained manually could be produced. Some of the more permanent ground rules are incorporated in the computer program code, per se. The tremendous flexibility designed into the program input permits the duplication or close approximation of the more variable ground rules.

As the complex set of ground rules utilized in the manual analysis became more easily handled/accommodated with the DORCA program, greater interest was expressed in conducting a one-for-one comparison between mechanized and manual analyses. For purposes of this comparison, the mission model used in one of the more recent and well documented manual analyses (Case 403 "Best Mix" model) was chosen to undergo the mechanized analysis. This report is dedicated to reporting the results of this analysis and its subsequent comparison with results obtained from the manual analysis.

3. GROUND RULES

Documented ground rules and assumptions upon which the manual traffic analysis was conducted are enumerated below. The capability to emulate these ground rules and assumptions in the DORCA computer program will be discussed as each is enumerated.

3.1 SHUTTLE PHASE-IN

The full operational capability of the Shuttle was phased-in over a three year (79 through 81) period. The maximum number of Shuttle flights permitted during those years were 14, 36, and 50 respectively.

There are no existing provisions within the DORCA program to duplicate the Shuttle phase-in operation in a direct manner. The operation can be closely approximated; however, doing so involves making several successive computer runs for the year involved. The first run would have no restrictions on Shuttle flights and would load all payloads and payload vehicles aboard Shuttles. Results of the first run would be used as a guide for constructing the input for a second run. For example, if 20 flights constituted the limit, the cargo loading assigned in the first 20 flights of the first computer run would be scheduled on Shuttles in the input data for the second run. The balance of the payloads for the years in question would then be assigned through the program in the normal manner to other vehicles available for service. A further iteration might be required to make vernier adjustments in cargo loading to account for differences in delivery modes of some cargo combinations but these adjustments should be relatively minor.

3.2 WTR LAUNCH SITE

WTR launch site is activated for Shuttle use one year after the ETR launch site. With DORCA, this constraint is handled directly by removing the Shuttle from the list of candidate vehicles for flights emanating from the WTR site for the first year.

3.3 SPACE TUG IOC

The date of Space Tug operational availability shall be 1985.

DORCA can accommodate this ground rule in a straightforward manner by specifying in the vehicle preference list that the Tug is unavailable for service until the year 1985.

3.4 EXPENDABLE UPPER STAGES

Expendable energy stages shall be used wherever necessary with the Space Shuttle. The implication in this ground rule is that perference shall be given to reusable upper stage vehicles in the payload delivery/retrieval missions, but that no mission shall be rejected because a reusable vehicle could not be used for performing the mission.

This ground rule would be handled in the DORCA program by including expendable upper stages in the vehicle preference list. The stages would be entered in such a manner as to require that all of the reusable vehicles be tried in the reusable mode first, the expendable vehicles next, and finally, the reusable vehicles in an expendable mode. The sequence in which the vehicles were to be tried, in each of the above categories, would be ordered according to performance capabilities.

3.5 ON-ORBIT ASSEMBLY CONSTRAINTS

No on-orbit assembly by means other than docking (capability available in 1985) shall be permitted, and the number of Shuttle flights in support of an orbit-to-orbit vehicle flight to a high energy destination shall not exceed two. In the DORCA computer program, different types of on-orbit assembly processes are not recognized, per se. Basically, it is assumed in the program that any combination of vehicle stages and payloads assigned to constitute an orbit-to-orbit flight can somehow be assembled into an integral unit on-orbit even though the stages and payloads may have been delivered to orbit piece by piece. Adherence to assembly constraints can only be controlled by controlling the individual subassemblies that may be shipped to orbit so that they undergo on-orbit assembly. To some degree this control is possible with the computer program. The DORCA cargo loading algorithm, when operating with the "capture" option invoked, is coded so that payloads can only be loaded on the upper stage of multistage orbit-to-orbit vehicles. This feature limits to a degree the possible combinations that can be shipped together to orbit on the Shuttle. Another feature that further limits combinations is the aspect of specifying a limit on the total volume (length) of payloads that can be loaded onto the upper stage of the orbit-to-orbit vehicle. With the program, a coupled package of stage and payloads on a Shuttle flight is attempted. If the coupled package cannot be accommodated by the Shuttle, the stage and the payloads are then transported separately to orbit via two Shuttle flights. If desired, the aforementioned volumetric limit for the orbit-to-orbit vehicle can be adjusted to assure stage and payload transport on a single Shuttle flight. The ground rule can be satisfied with the program; however, such satisfaction is more restrictive than was intended since in the manual analysis payloads could be loaded on any or all stages of multistaged vehicles.

3.6 LOW-COST Vs CURRENT PAYLOAD DESIGNS

If a low cost payload will not fit in the Shuttle without on-orbit assembly but a current design will, then the latter accommodation will be implemented.

This ground rule can be handled with DORCA in either one of two ways. If the user were astute enough to catch the discrepancy while compiling input data, he could change the input data. If however, he did not, the program could not "fly" the payload and would print an error message indicating that the payload would not fit in the Shuttle. A second run, with corrected input data, would then have to be made on the computer.

3.7 PAYLOAD LENGTH

Payloads to 60 feet long will be accommodated in a 60-foot payload bay.

DORCA provides for the specification of volumetric (length) factors for both vehicles and cargo items (payloads). As long as the payload length (or the aggregate length of all payloads, if more than one) is equal to or less than the factor specified for the vehicle, the payload will be accommodated.

3.8 MAXIMUM NUMBER OF PAYLOADS/FLIGHT

The maximum number of payloads permitted on any given Shuttle flight shall be three.

This restriction can be inserted directly into the DORCA input and will be complied with in the execution of the program.

3.9 TWO-SITE OPERATION

Two-site operation is assumed to give the Shuttle coverage of all orbit inclinations of interest.

As far as a concern in the DORCA program, these requirements need only be defined in the program input by inserting required data in the leg table and the vehicle table.

3.10 ADDITIONAL WORKING RULES

During the course of conducting the mechanized analysis, the need for additional guidance in the form of working rules was required. The following working rules were formulated and checked for consistency with those used to conduct the manual analyses.

a. The maximum number of payloads that can be accommodated on any given space Tug or Centaur flight shall be three and on any given Agena, Delta, or space Tug (WTR launch) flight, it shall be two. Like the Shuttle payload limitation, this limitation can be accommodated by insertions in the DORCA input data.

b. The number of propulsive stages that may be accommodated on any given Shuttle flight shall be one. There are no provisions in DORCA to comply with this working rule in a direct manner. However, there are several provisions built into DORCA and several input data manipulations available that permit the rule to be closely approximated (if judiciously applied in combinations to fit the particular situation) without unduly influencing the normal shipment of other payloads.

Other minor procedural details had to be clarified and coordinated with the personnel involved in the manual analysis; however, those discussed in this section are the important ones which provided the direction for both the manual and the mechanized analysis.

4. METHODOLOGY

The basic methodology and philosophy applied to conduct of the mechanized traffic analysis is described below.

The same satellite program mission model that was utilized in conducting the most recent manual analysis (Case 403 "Best Mix") was used in the mechanized analysis. The basic reasons for selecting the more recent were: (a) the ground rules had been well documented; and, (b) some of the more subtle procedural matters influencing the results (but not normally documented) were still fresh in mind. Also, by using the same model, there was the assurance that the same payload definitions and delivery schedules would be used and that the same candidate vehicles would be considered.

The automatic features of the DORCA program were used wherever possible in order to calibrate accuracy and compatibility with the manual analysis procedures, which have gained general acceptance throughout the NASA organization. The primary DORCA features involved were the following:

a. The capability of computing orbit-to-orbit vehicle capabilities to/from the various payload operational orbits.

b. The capability of performing "capture" of the payloads by the candidate vehicles in an automatic mode.

In several cases, it was necessary to override the automatic operation and make a-priori payload-vehicle assignments to coincide with minor differences between the manual and mechanical capability. For example, during the Shuttle phase-in period, the ground rules specified a maximum number of flights that the Shuttle could fly each year. In the manual analysis, however, the number of Shuttle flights flown in those years were below maximums specified. Since the method (as discussed in Section 3 of this report) to approximate this ground rule required a fixed rather than "less than" number of flights as a criterion and since the procedure would require a-priori vehicle-payload assignments anyway, expendable launch vehicle assignments identical to those in the manual analysis were made. The balance of the payload traffic was left so that the computer program could be used to determine loading aboard the Shuttle.

Other instances in which a-priori assignments were made involved the utilization of expendable orbit-to-orbit stages after the space tug had become operational. There were a few instances in the manual analysis where it proved to be more cost effective to revert to expendable vehicle operations momentarily rather than continue with reusable vehicles. These discontinuities or anomalies were usually associated with larger payloads going to sparsely populated orbits, where either a Tug would have to be expended to accomplish the mission or a tandem Tug would have to be flown to accomplish the mission in a reusable mode. In those cases it was cheaper to use an expendable vehicle than either of the other alternatives.

It had been planned to utilize the DORCA propellant off-loading option in the mechanized analysis; however, off-loading was not utilized in conducting the manual analysis. Therefore, the provision was not employed in the analysis. However, an off-loaded Tug and an off-loaded tandem Tug were both defined and utilized in the mechanized analysis.

The off-loaded Tug was utilized for those cases where a fully loaded Tug and the Tug payload could not be loaded together aboard the Shuttle due to excessive weight, and a Tug with a full propellant load was not required to perform the mission. In some cases, when the Tug was propellant off-loaded to the point of just being able to fly the mission, Tug weight was sufficiently reduced to permit Tug and payload together to meet Shuttle weight restrictions and therefore only one Shuttle flight was needed.

The off-loaded tandem Tug was included to help in complying with the ground rule that no orbit-to-orbit mission shall require more than two supporting

Shuttle flights. It is conceivable that three Shuttle flights could be scheduled with DORCA to support a tandem Tug mission. For instance, three Shuttle flights would be required to support the mission in those cases where: (1) a tandem Tug was required to perform the mission but the full capability was not required; (2) the payload was too heavy to be transported in the Shuttle with a fully fueled Tug; and, (3) off-loading of the first stage Tug was not allowed. On the other hand, it is possible that the mission would require only two Shuttle flights if: (1) the first stage of the vehicle could be propellant off-loaded to reduce weight (only stage that the program will automatically off-load is the lower stage); and, (2) the combined weight and volume of the off-loaded stage and the payload would comply with Shuttle constraints. Therefore the off-loaded tandem Tug consisting of an off-loaded first stage and a fully loaded upper stage was input to accommodate this situation.

In this cases where DORCA loaded two propulsive vehicles on the same Shuttle flight, a combination of techniques (coupling cargo items and increasing vehicle lengths) was used to eliminate the multiple transport. The number of cases involved was small enough to evaluate any undue influences on the total traffic picture due to the changes. No unrealistic changes were noted due to the coupling operations performed or to "fibbing" about the vehicle length.

5. RESULTS

The results obtained from the mechanized analysis was initially within five percent of the manual results previously obtained. The initial runs on DORCA were analyzed to assure that all of the ground rules and working rules used in the manual analysis were adhered to in the mechanized analysis. It was in the analysis of these initial runs that most of the discrepancies in ground rules were uncovered and where working rules previously employed but subsequently forgotten were recalled. These discrepancies and forgotten rules (most of which were discussed in the previous chapter) were corrected in the later runs. Most of the corrections required were minor in nature and the results subsequently obtained compared within one percent of the manual results. Figure 1 presents a comparison, by fiscal year, of the overall Shuttle traffic rates obtained in the two analyses. Figures 2 through 7 give comparisons for the various program elements comprising the overall mission model.

NOTE: SORTIE AND SPACE STATION NOT INCLUDED

YEAR	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
STUDY 2.1 RESULTS (CASE 403 3/16/72)*	8	22	27	22	28	21	38	24	32	31	35	25	313
DORCA II CAPTURE	9	21	30	20	27	21	36	28	33	29	31	24	309
DORCA II DIFFERENCE	+1	-1	+3	-2	-1	-0	-2	+4	+1	-2	-4	-1	-4

*AS REPORTED TO NASA TASK MONITOR IN DATA PACKAGE OF 19 MARCH 1972

Fig. 1. Comparison of Manual (Study 2.1) and Mechanized (DORCA) Capture Analysis Results - Total Mission Model

CODE	NO.	NAME	CASE 403	DORCA II	DORCA Δ
NAS-1CR	15	LARGE STELLAR TELESCOPE	11.0	9.9	- 1.1
NAS-2CR	17	LARGE STELLAR OBSERVATORY	9.0	8.4	- 0.6
NAS-3CR	19	LARGE RADIO OBSERVATORY	5.5	5.3	- 0.2
NAS-4CR	13	HI ENERGY ASTRONOMICAL OBS	19.0	16.4	- 2.6
NAS-6CE	10	SOLAR ORBIT PAIR A	2.0	1.9	- 0.1
NAS-8CE	11	SOLAR ORBIT PAIR B	2.0	1.4	- 0.6
NAS-9CE	12	OPTICAL INTERFEROMETER	1.0	1.0	+ 0.1
NAS-11CE	9	RADIO INTERFEROMETER	1.0	1.1	+ 0.1
NAS-14ACR	1	ASTRONOMY EXPLORER A	8.5	5.6	- 2.9
NAS-14BCR	2	ASTRONOMY EXPLORER B	5.5	3.2	- 2.3
NAS-15LCE	6	ORBITING SOLAR OBSERVATORY	1.0	0.4	- 0.6
		TOTALS	65.5	54.7	- 10.8

Fig. 2. Comparison of Manual (Study 2.1) and Mechanized (DORCA) Capture Analysis Results - NASA Astronomy Program

CODE	NO.	NAME	CASE 403	DORCA II	DORCA Δ
NSP-1LCR	3	LOW MAGNETOSPHERE	10.0	12.9	+ 2.9
NSP-2LCR	4	MID MAGNETOSPHERE	10.5	12.1	+ 1.6
NSP-3LCE	5	UPPER MAGNETOSPHERE	12.0	9.9	- 2.1
NSP-6LCR	7	GENERAL RELATIVITY - POLAR	1.5	2.0	+ 0.5
NSP-7LCE	8	GENERAL RELATIVITY - B, D.	2.0	1.5	- 0.5
		TOTALS	36.0	38.4	+ 2.4

Fig. 3. Comparison of Manual (Study 2.1) and Mechanized (DORCA) Capture Analysis Results - NASA Space Physics Program

CODE	NO.	NAME	CASE 403	DORCA II	DORCA Δ
NEO-2LCR	21	POLAR EARTH OBSERVATIONS	10.0	11.0	+ 1.0
NEO-3LCR	22	SYNC EARTH OBSERVATIONS	4.5	4.9	+ 0.4
NEO-4LCR	27	SYNC EARTH RESOURCES	5.0	6.8	+ 1.8
NEO-5LCR	23	EARTH PHYSICS - POLAR	6.0	7.0	+ 1.0
NEO-6CR	25	TIROS	3.0	1.5	- 1.5
NEO-8LCE	24	SYNC METEOROLOGICAL	1.5	0.9	- 0.6
NEO-17 LCE	26	POLAR EARTH RESOURCES	5.0	6.0	+ 1.0
		TOTALS	35.0	38.1	+ 3.1

Fig. 4. Comparison of Manual (Study 2.1) and Mechanized (DORCA) Capture Analysis Results - NASA Earth Observation Program

CODE	NO.	NAME	CASE 403	DORCA II	DORCA Δ
NCN-1CR	28	APPLICATIONS TECHNOLOGY	12.0	13.8	+ 1.8
NCN-2ALCR	29	SMALL APPLICATIONS TECH - SYNC	8.1	5.1	- 3.0
NCN-2BLCR	30	SMALL APPLICATIONS TECH - POLAR	9.0	8.9	- 0.1
NCN-3ALCE	31	COOPERATIVE APPL - SYNC	0.6	0.8	+ 0.2
NCN-3BLCR	32	COOPERATIVE APPL - POLAR	1.0	1.7	+ 0.7
NCN-5CR	36	TRACKING AND DATA RELAY	8.8	8.7	- 0.1
NCN-11CE	33	MEDICAL NETWORK	EXP	EXP	----
NCN-12CE	34	EDUCATIONAL BROADCAST	2.0	1.9	- 0.1
NCN-13CR	35	FOLLOW-ON SYSTEMS DEMO	16.0	17.3	+ 1.3
		TOTALS	57.5	58.2	+ 0.7

Fig. 5. Comparison of Manual (Study 2.1) and Mechanized (DORCA) Capture Analysis Results - NASA Communications and Navigation Program

CODE	NO.	NAME	CASE 403	DORCA II	DORCA Δ
NPL-1CE	50	MARS VIKING	1.0	1.0	----
NPL-5LCE	52	VENUS EXPLORER/ORBITER	1.0	1.0	----
NPL-6CE	53	VENUS RADAR MAPPING	1.0	1.0	----
NPL-7LCE NPL-8LCE	54	VENUS EXPLORER/LANDER	2.0	2.1	+ 0.1
NPL-1CE	56	GRAND TOUR	EXP	EXP	----
NPL-11CE	55	JUPITER PIONEER	2.0	1.8	- 0.2
NPL-13CE	57	JUPITER/TOPS ORBITER/PROBE	2.0	2.0	----
NPL-14CE	58	URANUS/TOPS ORBITER/PROBE	2.0	2.0	----
NPL-15CE	59	ASTEROID SURVEY	1.0	0.9	- 0.1
NPL-18 CE	60	COMET RENDEZVOUS	2.0	1.9	- 0.1
NPL-19CE NPL-20CE	51	MARS SAMPLE RETURN	4.0	4.4	+ 0.4
		TOTALS	18.0	18.1	+ 0.1

Fig. 6. Comparison of Manual (Study 2.1) and Mechanized (DORCA) Capture Analysis Results - NASA Planetary Program

CODE	NO.	NAME	CASE 403	DORCA II	DORCA Δ
NEO-11CR	78	SYNC EARTH RESOURCES	4.0	3.3	- 0.7
NEO-7CR	75	TOS METEORLOGICAL	11.0	9.4	- 1.6
NEO-15CR	76	SYNC METEORLOGICAL	11.0	5.8	- 5.2
NEO-16LCR	77	POLAR EARTH RESOURCES	18.0	18.0	----
NCN-7CR	70	COMMUNICATIONS SAT	9.0	8.0	- 1.0
NCN-8CR	71	U.S. DOMESTIC COMM	21.0	27.9	+ 6.9
NCN-9CR	72	FOREIGN DOMESTIC COMM	14.0	17.7	+ 3.7
NCN-10ACR	74	NAVIGATION/TRAFFIC CONT	6.0	5.8	- 0.2
NCN-10BCR	73	NAVIGATION/TRAFFIC CONT	7.0	5.6	- 1.4
		TOTALS	101.0	101.5	+ 0.5

Fig. 7. Comparison of Manual (Study 2.1) and Mechanized (DORCA) Capture Analysis Results - Non-NASA Program

6. CONCLUSIONS

From the results obtained and the comparisons made it is clear that results of the manual analysis can be duplicated with the DORCA program to a very high degree. Furthermore, the time required to obtain the desired analysis is far less than required in the manual mode. It is true that the initial set up of input card files is a time consuming task but once that file has been compiled, performing the analysis with DORCA is a speedy process. Perturbating existing mission models or compiling a new one from either existing mission models or existing payloads requires very little effort.

In addition, the printed output from DORCA provides a neat record which the engineer may analyze to assure that all ground rules have been complied with and/or utilize to synthesize new, more efficient ones. The printout also provides a convenient and accurate historical record and provides access to the ground rules and assumptions utilized in the analysis.

The ability to perform analyses in a consistent manner is another distinct benefit of the mechanized program. Differences in analytical results as a result of perturbating the input mission model and/or vehicles can be relied upon to represent actual deltas since the capture was done in precisely the same manner as before.

If the ground rules for conducting capture analyses remain unchanged and if DORCA is to be employed to perform the task, several changes and/or additions need to be made to the program code. Provisions to deal directly with restrictions on payload or vehicle combinations permitted with respect to their transportation need to be included.

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