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HOUSTON ASTRONAUTICS DIVISION

SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT
DESIGN NOTE NO. 1.4-3-8
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SUBJECT: Rendezvous Requirements and Candidate Worst Case Flights from the October 1973 Space Shuttle Traffic Model

DATE: 9 December 1974

1.0 SUMMARY

Data appearing in the October 1973 Space Shuttle Traffic Model were analyzed to determine the rendezvous requirements for the proposed shuttle flights occurring between 1980 and 1991. Four families of flights have been identified, namely, single-payload rendezvous, multiple-payload rendezvous, payload and tug rendezvous, and tug only rendezvous. Charts have been prepared which summarize the respective data. Observations are presented for each of the four flight families, and worst case flights are proposed from each family for further analysis.

2.0 INTRODUCTION

The Orbital Trajectory Analysis Task Assignment, Reference 1, specifies support activity in the area of nominal rendezvous sequence refinements. Baseline reference missions and groundrules for nominal rendezvous sequences appear in References 2 and 3, but there is no indication of the number of flights within a given traffic

model for which these sequences will be appropriate. The nominal rendezvous sequence selected for shuttle use should be compatible with at least a large sector of the current traffic model. The object of the present study is to analyze the flights contained in the best available traffic model (assumed to be that given in Reference 4) for the purposes of: 1) identifying flight families within the traffic model which have similar mission parameters and/or rendezvous requirements, and 2) proposing worst case flights from each family as candidates for future profile investigations.

3.0 DISCUSSION

Three hundred thirty five of the flights presented in Reference 4 will require orbiter rendezvous capability. A rendezvous requirement exists whenever a payload and/or tug retrieval is indicated on the Shuttle Cargo Manifest (Table 4 of Reference 4). Sortie flights returning with only Spacelabs and/or Pallets (L,P,L+P) will not require rendezvous and are not included herein. Flight numbers were assigned to Department of Defense (DOD) flights in Reference 4 however, orbital data are not given on the manifest. This is unfortunate because 137 of the 335 flights fall into the DOD category.

The 335 rendezvous flights were categorized into the following four families: (the total number of flights within each family, for the 1980-1991 time period, is indicated in parentheses)

Family 1) Orbiter/Single-Payload Rendezvous Without Tug Retrieval (34)

Family 2) Orbiter/Multiple-Payload Rendezvous Without Tug Retrieval (23)

Family 3) Orbiter/Payload Rendezvous With Tug Retrieval (26)

Family 4) Tug Retrievals Only (252)

All target orbits specified in Reference 4 were circular and, where multiple rendezvous were required, coplanar. Within all of the above families, individual flights may include multiple deliveries and/or sorties involving Spacelabs and/or Pallets.

4.0 RESULTS

Graphic and tabular data pertaining to each flight family will now be considered.

4.1 Orbiter/Single-Payload Rendezvous Without Tug Retrieval -

Table 1 summarizes flights requiring a single rendezvous by the orbiter which are classified as Family 1 flights. Column one refers to the year in question; and the following columns give flight number (numerator) and target orbit altitude and inclination (denominator) respectively. Flights launched from the Western Test Range (WTR) are superscripted with the letter W.

TABLE 1 - Summary of Family 1 Flights (Orbiter/Single-Payload Rendezvous Without Tug Retrieval)

YEAR	FLIGHT NUMBER CIRCULAR TARGET ORBIT ALTITUDE, n.mi/INCLINATION, deg.				
1980	2 250/28.5				
1981	15 270/28.5				
1982	9 270/28.5				
1983	17[W] 300/99	18[W] 300/97	19[W] 300/97		
1984	20[W] 300/99	21[W] 300/97	22 270/28.5		
1985	19[W] 300/97	21 270/28.5			
1986	20 200/28.5	21[W] 300/99	22[W] 300/97	26 270/28.5	
1987	18[W] 300/99	19[W] 300/97	20 190/28.5		
1988	15 340/28.5	17[W] 300/99	18[W] 300/97	19 200/28.5	21 270/28.5
1989	15[W] 300/99	16[W] 300/97	18 200/28.5		
1990	18[W] 300/99	19[W] 300/97	20 270/28.5	24 270/28.5	
1991	14 340/28.5	15[W] 300/99	16[W] 300/97	18 270/28.5	

W=WESTERN TEST RANGE

TABLE 2 - Target Orbit Requirements for Family 1 Flights

CIRCULAR TARGET ORBIT ALTITUDE, n.mi.	NUMBER OF FLIGHTS
340	2
300	18
270	9
250	1
200	3
190	1

On Table 2 circular target orbit altitude requirements are summarized for Family 1 flights along with corresponding frequencies of occurrence.

The following observations may be made by inspecting the Family 1 data:

a) The total number of flights in this family is 34.

b) The first flight in this family occurs in 1980.

c) The launch frequency for Family 1 flights is one per year for the first three years, then about three to four per year thereafter.

d) The maximum yearly frequency is five and it occurs in 1988.

e) Over half (18) of the flights are launched from WTR and call for 300 n.mi. target orbits.

f) Over one fourth (9) of the flights are launched from Kennedy Space Center (KSC) and call for 270 n.mi. target orbits.

g) The lowest target orbit altitude called for is 190 n.mi. and there is one such flight (Flight 20 in 1987).

h) The highest target orbit altitude called for is 340 n.mi. and there are two such flights (Flight 15 in 1988 and Flight 14 in 1991).

i) Three flights call for 200 n.mi. target orbits.

j) One flight calls for a 250 n.mi. target orbit.

k) Sixteen flights are launched from KSC; 18 from WTR.

4.2 Orbiter/Multiple-Payload Rendezvous Without Tug Retrieval - Table 3 is a synopsis of multiple rendezvous flight data for Family 2 flights. Column one gives the applicable year and columns two through four contain information on individual flights within that year. The numerators of the entries are flight numbers, and the demoninators give the circular orbit altitudes of the targets.

Two entries in the denominator indicates two payload retrievals by the orbiter, three indicates three retrievals and so on. All superscripted entries refer to flights launched from WTR, while the unsuperscripted ones refer to KSC launches.

On Table 4 the number of flights requiring 2, 3, and 4 rendezvous flights are given. Also shown on the table are the number of flights for which two or more of the targets are at the same circular orbit altitude.

Table 5 gives the orbit inclination requirements for the multiple rendezvous flights.

The order of retrieval was not specified in Reference 4 for any of the multiple rendezvous flights. If rendezvous were to be performed between consecutive target orbits, some interesting observations may be made regarding their relative orbit altitudes and this information is presented in Table 6.

TABLE 3 - Summary of Family 2 Flights (Orbiter/Multiple-Payload Rendezvous Without Tug Retrieval)

YEAR	FLIGHT NUMBER $H_1/H_2/\ldots H_N$(n.mi.)		
1980	1 297/270	3 300/300	
1981	13 297/297/340	14 300/300	
1982	6 297/340/270	7 300/300	8[a] 300/300
1983	15 340/200	16 300/300	20[b] 216/216/216
1984	19 340/300/270/270		
1985	15 340/200	16[a] 300/300	
1986	19 340/190		
1987	17 340/200/270		
1988	16 190/270		
1989	14 340/200	17 200/190	19[c] 200/200/200
1990	17 340/190	21 200/200	
1991	17 200/190/200	19[c] 200/200	

THE FOLLOWING SUPERSCRIPTS REFER TO WTR LAUNCHES:

a INCLINATION = 90°

b INCLINATION = 98°

c INCLINATION = 99°

NOTE: ALL UNSUPERSCRIPTED ENTRIES REQUIRE INCLINATIONS OF 28.5° (i.e. KSC LAUNCHES)

ALL TARGET ORBITS ARE CIRCULAR

TABLE 4 - FAMILY 2 FLIGHTS REQUIRING TWO, THREE, AND FOUR RENDEZVOUS

No. of Rendez-vous required	Total Number of Flights	Number of Flights With:	
		2 or More Targets at Same Altitude	3 Targets at Same Altitude
2	16	8	—
3	6	4	2
4	1	1	—

TABLE 5 - INCLINATION REQUIREMENTS FOR FAMILY 2 FLIGHTS

Inclination	Number of Flights
28.5°	18
90.0°	1
98.0°	2
99.0°	2

TABLE 6 - ORBIT ALTITUDE DIFFERENCES BETWEEN CONSECUTIVE RENDEZ-VOUS FOR FAMILY 2 FLIGHTS

Orbit Altitude Difference Between Consecutive Rendez.	Possible Occurrences for all Flights
150 n.mi.	2
140 n.mi.	4
80 n.mi.	1
70 n.mi.	5
43 n.mi.	3
40 n.mi.	1
30 n.mi.	2
27 n.mi.	2
10 n.mi.	3
0 n.mi.	17

The following observations were made regarding the Family 2 flights:

a) There are twenty-three flights in this family.

b) Eighteen flights are launched from KSC; Five from WTR.

c) The average launch rate is about two per year.

d) The maximum number of flights occurring in a single year is three (occurs in 1982, 1983, and 1989).

e) The maximum number of rendezvous for a single flight is four (Flight 19 in 1984).

f) The number of flights requiring two rendezvous is sixteen.

g) The number of flights requiring three rendezvous is six.

h) The number of flights requiring four rendezvous is one.

i) Half of the sixteen two-rendezvous flights call for both targets to be at the same altitude.

j) Two of the six three-rendezvous flights call for all three targets to be at the same altitude; two call for two of the three targets to be at the same altitude; and two call for all three targets to be at different altitudes.

k) For the single four-rendezvous flight, two of the four targets are specified to be at the same altitude.

l) The total number of flights having two or more targets at the same orbit altitude is thirteen (56.5% of the flights).

m) The total number of flights for which three or more targets are at the same orbit altitude is two.

n) The minimum observed target orbit altitude is 190 n.mi.

o) The maximum observed target orbit altitude is 340 n.mi.

p) The maximum altitude difference between consecutive targets for a given flight is 150 n.mi.

4.3 Orbiter/Payload Rendezvous With Tug Retrieval -

The Family 3 flight data summarized in Table 7 pertain to flights for which the orbiter retrieves both a payload and a tug. On one occasion (flight 16 in 1987) the orbiter retrieves two payloads (i.e. a multiple rendezvous) and a tug. Column one of Table 7 gives the year and columns two through six contain information on the flights for that year. The numerators are flight numbers and the two denominator entries refer to tug and payload orbits respectively. A letter code is used for the latter and respective code definitions are given in Tables 8 and 9. The asterisked entries in Table 7 represent flights for which an empty tug is retrieved (i.e. the tug itself has not retrieved a payload).

Since the orbiter itself is not capable of achieving high energy orbits such as the synchronous equatorial, tugs will be used for payload placement and retrieval at these altitudes. After the tug completes its mission it will then be placed in a lower orbit and

TABLE 7 - SUMMARY OF FAMILY 3 FLIGHTS (ORBITER/PAYLOAD RENDEZVOUS WITH TUG RETRIEVAL)

Year	Flight Number / Tug Orbit/Payload Orbit				
1984	11 / Z/A				
1985	6[a] / W/A	10 / S/A			
1986	13[a] / S/A	14 / S/A	15 / S/B		
1987	7 / W/B	11 / S/A	12 / X/D	13[a] / S/A	16[a] / X/(D/D[b])
1988	6 / S/B	7[a] / S/A	8[a] / S/A	9[a] / S/C	
1989	3 / W/B	11 / S/A	12[a] / S/A		
1990	13[a] / S/B	14[a] / S/A	15[a] / S/A	16[a] / S/C	
1991	4 / W/B	6[a] / Y/E	8 / S/A	10[a] / S/A	

a Orbiter Retrieves Empty Tug

b Multiple orbiter rendezvous (both targets at same altitude)

TABLE 8 - TUG ORBIT DESCRIPTIONS FOR FAMILY 3 FLIGHTS

Code	Tug Departure Orbit Description (H_A/Hp/INCL)	Number of Flights
S	19323/19323/0	18
W	38646/38646/28.5	4
X[W]	920/920/103	2
Y[W]	1900/140/90	1
Z	1080/540/28.0	1

W = WTR Launch

TABLE 9 - PAYLOAD ORBIT DESCRIPTIONS FOR FAMILY 3 FLIGHTS

Code	Payload Orbit Description (H_A/H_p/INCL)	Number of Flights
A	300/300/28.5	15
B	297/297/28.5	5
C	270/270/28.5	3
D[W]	216/216/90.0	2
E[W]	200/200/98.0	1

W = WTR Launch

Note: H_A and H_p are in n.mi.; INCL is in deg.

will be retrieved by the orbiter. The tug orbits shown in Table 8 are these high-energy tug departure orbits for Family 3 flights and do not represent orbiter/tug rendezvous orbits. No orbiter/tug rendezvous orbit descriptions appear in Reference 4, however, a 160 n.mi. circular orbit is cited for this in Reference 2. Column one of Table 8 gives a letter code (per Table 7); column two, the high energy tug departure orbit; and column three, the total number of flights required for this particular orbit.

The orbiter is scheduled to retrieve low orbit payloads. A tabulation of the orbiter target orbits for Family 3 flights is given in Table 9. Column one gives a letter code compatible with those in Table 7; column two, the target orbit description; and column three, the total number of flights for the given orbit.

The following observations were made on flights in Family 3:

a) The total number of flights in Family 3 is twenty-six.

b) There are no flights before 1984 and only one flight in 1984.

c) The maximum number of flights in a single year is five (1987).

d) The number of times an orbiter retrieves an empty tug is fourteen (54 percent of the flights).

e) The number of times the tug comes down from a synchronous equatorial orbit is eighteen (69 percent of the flights).

f) The number of times the orbiter target is at an altitude of 297 or 300 n.mi. is 20 (77 percent of the flights).

g) A single flight (number 16 in 1987) requires two orbiter rendezvous and a tug retrieval.

h) The number of flights originating from WTR is three.

4.4 Tug Retrieval Only - The Family 4 flights may be divided into four subclasses, namely:

A) flights for which no payload is retrieved by the tug

B) flights for which a single payload is retrieved by the tug

C) flights for which two payloads are retrieved by the tug

D) Department of Defense (DOD) tug retrieval flights for which no payload and orbit information are presented in the reference.

4.4A No Payload Retrieved by Tug - Information pertaining to the 82 flights within this subclass is summarized in Table 10. Column one gives the year, and the remaining columns contain flight number (numerator) and orbit information (denominator). The tug must return from the indicated orbit before it can be retrieved at a lower altitude by the orbiter. Two entries in the denominator imply that the tug has made two deliveries and the tug orbit prior to its transfer to a lower orbit may be either of these. The letter coded orbit designations appearing in Table 11 apply to Table 10. Table 11 also presents the number of flights for which a particular delivery orbit is required.

TABLE 10 - SUMMARY OF FAMILY 4 SUBCLASS A FLIGHTS (TUG RETRIEVAL ONLY: NO PAYLOAD RETRIEVED BY TUG)

Year	Flight Number / Tug Delivery Orbit(s)										
1981	1/H	2/H	6/A/S	7/F	8/C/S	9/S/S	10/S/S	11/S/S	12/S		
1982	1/H	2/S/S	3/S/S	4/S/S	5/S						
1983	1/H	2/H	5/G	6/S/S	7/S	8/S	9/S	10/S	11/S	12/S/S	13/S/S
1984	1/H	2/H	7/F	8/H	9/H	10/H					
1985	1/U	2/H	3/U	4/H	5/G/S	7/H	8/H	12/S	13/S	14[W]/B	
1986	1/H	2/U	4/U	7/H	8/H	9/H	10/H	11/H	16/S	18[W]/B	
1987	1/U	4/H	6/H	8/H	9/F	10/H	14/S/S				
1988	1/H	2/U	5/H	10/S/S	11/S/S	12[W]/B	13/S/S	14/S/S			
1989	1/U	8/H	9/H	10/H	13/S/S						
1990	1/U	3/U	5/U	11/F	12/H						
1991	1/U	3/H	9/H	11/S	12/S	13/S					

W = WESTERN TEST RANGE

Code	Tug Payload Delivery Orbit [H_A(n.mi)/H_p(n.mi)/Incl.(deg)]	Number of Flights*
S	19323/19323/0	31
A	2000/1000/28.5	1
B[W]	920/920/103	3
C	1080/540/28	1
F	6900/6900/55	4
G	19323/19323/28.5	2
H	ESCAPE	32
U	UNSPECIFIED	11

TABLE 11 - TUG ORBIT DESCRIPTIONS FOR FAMILY 4 SUBCLASS A FLIGHTS

W = WESTERN TEST RANGE

* Three flights utilize two different Tug Payload Retrieval Orbits

4.4B Single Payload Retrieval by Tug - The twenty-two flights in this subclass are indicated on Table 12. Flight number (numerator) and orbit designation (denominator) appear opposite each appropriate year. Table 13 contains the letter codes used for orbit designation in Table 12. The number of flights requiring payload retrieval in the designated orbit by the tug is shown in column three of Table 13.

4.4C Two Payloads Retrieved by Tug - On eleven flights the tug is required to retrieve two payloads, and relevant information for this subclass is presented in Table 14. Flight number (numerator) and orbit designations (denominator) appear opposite each appropriate year. Letter codes explaining orbit designations are contained in Table 15. Also shown on Table 15 are the number of flights for which a particular tug/payload retrieval orbit is specified.

4.4D DOD Tug Retrievals - Although there are 137 flights in this subclass, no orbit descriptions appear in Reference 4. Table 16 presents the total number of DOD tug retrieval flights per year. Both KSC and WTR launch frequencies are shown.

The following observations may be made for Family 4 flights:

a) There are 252 flights requiring tug retrieval only by the orbiter (Family 4).

b) Subclass A (no payload retrieval by tug) contains 82 flights.

TABLE 12 - SUMMARY OF FAMILY 4 SUBCLASS B FLIGHTS (TUG RETRIEVAL ONLY: SINGLE PAYLOAD RETRIEVED BY TUG)

Year	Flight Number / Tug Orbit						
1984	$\frac{4^W}{D}$	$\frac{5^W}{E}$	$\frac{6}{F}$	$\frac{12}{S}$	$\frac{13}{S}$	$\frac{14}{S}$	$\frac{16^W}{B}$
1985	$\frac{9}{S}$	$\frac{11}{S}$					
1986	$\frac{6}{G}$	$\frac{12}{S}$	$\frac{17}{S}$				
1987	$\frac{15}{S}$						
1988	$\frac{4^W}{B}$						
1989	$\frac{4^W}{D}$	$\frac{5^W}{B}$	$\frac{6}{A}$	$\frac{7}{S}$			
1990	$\frac{7^W}{D}$	$\frac{8^W}{B}$	$\frac{10}{F}$				
1991	$\frac{5^W}{D}$						

TABLE 13 - TUG ORBIT DESCRIPTIONS FOR FAMILY 4 SUBCLASS B FLIGHTS

Code	Tug Payload Retrieval Orbit [H_A(n.mi)/H_p(n.mi)/Incl.(deg)]	Number of Flights
S	19323/19323/0	9
A	20000/1000/28.5	1
B	920/920/103^W	4
D	1900/140/90^W	4
E	790/790/102^W	1
F	6900/6900/55	2
G	19323/19323/28.5	1

W = WESTERN TEST RANGE

TABLE 14 - SUMMARY OF FAMILY 4 SUBCLASS C FLIGHTS (TUG RETRIEVAL ONLY: TWO PAYLOADS RETRIEVED BY TUG)

Year	Flight Number Tug Orbit 1/Tug Orbit 2			
1984	3 G/A	15[W] B/B	17 S/S	18 S/S
1987	2 S/C			
1988	3 S/S			
1989	2 S/S			
1990	4 S/S	6 S/A	9 S/S	
1991	7 A/S			

W = WESTERN TEST RANGE

TABLE 15 - TUG ORBIT DESCRIPTIONS FOR FAMILY 4 SUBCLASS C FLIGHTS

Code	Tug Payload Retrieval Orbit [H_A(n.mi)/H_p(n.mi)/Incl.(deg)]	Number of Flights*
S	19323/19323/0	9
A	20000/1000/28.5	3
B^W	920/920/103	1
C	1080/540/28	1
G	19323/19323/28.5	1

W = WESTERN TEST RANGE

* Four flights utilize two different Tug Payload Retrieval Orbits

TABLE 16 - SUMMARY OF FAMILY 4 SUBCLASS D FLIGHTS
(T'G RETRIEVAL ONLY: DOD TUG RETRIEVALS)

Year	KSC	WTR	Total
1981	2	0	2
1982	9	0	9
1983	11	6	17
1984	15	4	19
1985	6	5	11
1986	9	4	13
1987	10	4	14
1988	11	3	14
1989	6	5	11
1990	13	3	16
1991	6	5	11
Total	98	39	137

c) Subclass B (single payload retrieved by the tug) contains 22 flights.

d) Subclass C (two payloads retrieved by tug) contains 11 flights.

e) Subclass D (DOD tug retrievals) contains 137 flights.

f) Thirty-two of the 82 flights in subclass A involve tug retrievals from escape orbits; 31 from synchronous equatorial orbits.

g) No subclass A flights occur before 1981 at which time 9 flights are proposed.

h) The maximum yearly rate for subclass A flights is 11 and occurs in 1983. Ten flights per year are proposed for both 1985 and 1986.

i) Eleven subclass A tug orbits were unspecified in the reference.

j) Only three subclass A flights are launched from WTR.

k) No subclass B flights occur before 1984 at which time the maximum yearly rate of seven flights is observed.

l) Nine of the twenty-three flights in subclass B invlove tugs retrieving a payload from a synchronous equatorial orbit.

m) Nine subclass B flights require launches from WTR.

n) No subclass C flights occur until 1984 at which time the maximum yearly rate of four flights is observed.

o) No subclass C flights occur in 1985 and 1986 and only one flight per year occurs in 1987, 1988, 1989, and 1991.

p) Six of the eleven subclass C flights call for both tug-retrieved payloads to be in synchronous equatorial orbits.

q) Three of the eleven subclass C flights call for only one of the two tug-retrieved payloads to be in a synchronous equatorial orbit.

r) Only one of the subclass C flights requires a WTR launch.

s) Ninety-eight of the 137 DOD flights (subclass D) are launched from KSC; Thirty-nine from WTR.

t) The maximum yearly launch rate for subclass D flights is nineteen and occurs in 1984.

u) No subclass D flights occur in 1980 and only two occur in 1981.

v) The maximum subclass D yearly launch rate from KSC is fifteen and occurs in 1984; The maximum subclass D yearly launch rate from WTR is six and occurs in 1983.

An overall summary by flight family is presented in Table 17 for the 335 rendezvous flights occuring within the 1980 to 1991 time period. For simplicity, only flight numbers have been included on the table. The reader is referred to the previous tables or to Reference 4 for additional details.

5.0 CONCLUSIONS

It would appear that a significant part of the nominal rendezvous profile evaluation subtask should deal with the evaluation and/or

TABLE 17 - SUMMARY OF ALL FLIGHTS FROM THE OCTOBER 1973 TRAFFIC MODEL REQUIRING ORBITER RENDEZVOUS CAPABILITY

Flight Numbers . [] = Family Totals, ( ) = Subclass Totals {}= Yearly Totals

Year	FAMILY 1 Single Rendezvous	FAMILY 2 Multiple Rendezvous	FAMILY 3 Rend.& Tug Retrieve	FAMILY 4 Tug Retrieval Only				$\sum_{K=1}^{4}( )_K$	$\sum_{n=1}^{4}[ ]_n$
				A. Empty Tug	B. One Payload	C. Two Payloads	D. DOD Tug		
1980	2 [1]	1,3 [2]	NONE [0]	NONE (0)	NONE (0)	NONE (0)	NONE (0)	[0]	{3}
1981	15 [1]	13,14 [2]	NONE [0]	1,2,6,7,8,9,10,11,12(9)	NONE (0)	NONE (0)	33,34 (2)	[11]	{14}
1982	9 [1]	6,7,8 [3]	NONE [0]	1,2,3,4,5 (5)	NONE (0)	NONE (0)	29-37 Incl. (9)	[14]	{18}
1983	17,18,19 [3]	15,16,20 [3]	NONE [0]	1,2,5,6,7,8,9,10,11,12, 13 (11)	NONE (0)	NONE (0)	43,45-60 Incl. (17)	[28]	{34}
1984	20,21,22 [3]	19 [1]	11 [1]	1,2,7,8,9,10 (6)	4,5,6,12,13,14,16 (7)	3,15,17,18 (4)	47,49-66 Incl. (19)	[36]	{41}
1985	19,21 [2]	15,16 [2]	6,10 [2]	1,2,3,4,5,7,8,12,13,14(10)	9,11 (2)	NONE (0)	53,55-64 Incl (11)	[23]	{29}
1986	20,21,22,26 [4]	19 [1]	13,14,15 [3]	1,2,4,7,8,9,10,11,16, 18 (10)	6,12,17 (3)	NONE (0)	54,56-67 Incl (13)	[26]	{34}
1987	18,19,20 [3]	17 [1]	7,11,12,13,16 [5]	1,4,6,8,9,10,14 (7)	15 (1)	2 (1)	47,49-61 Incl. (14)	[23]	{32}
1988	15,17,18,19,21[5]	16 [1]	6,7,8,9 [4]	1,2,5,10,11,12,13,14(8)	4 (1)	3 (1)	50,52-64 Incl. (14)	[24]	{34}
1989	15,16,18 [3]	14,17,19 [3]	3,11,12 [3]	1,8,9,10,13 (5)	4,5,6,7 (4)	2 (1)	46,48-57 Incl. (11)	[21]	{30}
1990	18,19,20,24 [4]	17,21 [2]	13,14,15,16 [4]	1,3,5,11,12 (5)	7,8,10 (3)	4,6,9 (3)	55,57-71 Incl. (16)	[27]	{37}
1991	14,15,16,18 [4]	17,19 [2]	4,6,8,10 [4]	1,3,9,11,12,13 (6)	5 (1)	7 (1)	50,52,54,56-63 Incl. (11)	[19]	{29}
TOTAL	[34]	[23]	[26]	(82)	(22)	(11)	(137)	[252]	{335}

definition of baseline shuttle rendezvous sensors, hardware, and software. Consequently, a few worst case flight profiles should be selected for further analysis which will help to refine the nominal rendezvous profile. Furthermore, these worst case profiles should be representative of flights proposed by mission planners. Operational data such as rendezvous sequence descriptions, desired order of rendezvous (for multiple rendezvous), degree of payload cooperation, phasing and geometry information, time constraints, etc., were not given in Reference 4, and therefore the orbital data presented in Reference 4 were used to select worst cases on the basis of their possible impact on the nominal sequence as given in Reference 2. Adopting the categorization used in the foregoing analysis, possible candidates for consideration as worst case flights are:

Family 1: Flight 20 in 1987 which requires a target orbit altitude of 190 n.mi. Only six out of the 335 rendezvous flights call for target orbit altitudes as low as 190 n.mi. No rendezvous were required below 190 n.mi. altitude.

Flight 15 in 1988 (or Flight 14 in 1991) which requires a target orbit altitude of 340 n.mi. Only eleven out of 335 rendezvous flights call for target orbit altitudes as high as 340 n.mi. None require higher altitudes.

Family 2: Flight 19 in 1986 which requires two rendezvous, one at the highest observed altitude (340 n.mi.), and the other at the lowest observed altitude (190 n.mi.)

Flight 19 in 1984 which requires four rendezvous, two of which must occur at the same orbit altitude.

Family 3: Flight 16 in 1987 which is launched from WTR and calls for two rendezvous at the same altitude and a tug retrieval.

Flight 7 in 1987 which is launched from KSC and calls for a rendezvous with a single payload at 297 n.mi. and retrieval of a tug which has previously retrieved a payload from a 38646 n.mi. circular orbit.

Family 4: Flight 2 in 1987 which requires a tug retrieval after the tug itself has retrieved two payloads, one from a synchronous equatorial orbit and the other from a 1080 by 540 n.mi. elliptical orbit.

Flight 15 in 1984 which is launched from WTR and requires a tug retrieval after the tug itself has retrieved two payloads, both of which occupy 920 n.mi. circular orbits.

6.0 REFERENCES

1. SSEOS Task Assignment No. 1.4-3-B, "Orbital Trajectory Analysis Support", McDonnell Douglas Technical Services Company, Inc., dated 6 May 1974.

2. JSC Internal Note No. 73-FM-47, Volumes I, II and III, Revision 1, "Space Shuttle System Baseline Reference Missions", Johnson Space Center, dated 8 May 1974.

3. JSC Memorandum FM34(74-165), "Guidelines and Constraints for the Rendezvous Phase in Reference Missions 1, 2, and 3B", Johnson Space Center, dated 11 September 1974.

4. NASA TM X-64751, Revision 2, "The October 1973 Space Shuttle Traffic Model", Marshall Space Flight Center, dated January 1974.

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