Maintenance and Operations Cost Model for DSN Subsystems

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A procedure is described which partitions the recurring costs of the Deep Space Network (DSN) over the individual DSN subsystems. The procedure results in a table showing the maintenance, operations, sustaining engineering and supportive costs for each subsystem.

I. Introduction

In an earlier article (Ref. 1) a procedure was described for obtaining an M&O cost model for the DSN. The procedure consisted of first transforming the Work Authorization Document (WAD) into a computer file for ease of manipulation. Then each of the more than 600 WAD accounts was studied to determine if it was a recurring cost or an implementation-related nonrecurring cost. The nonrecurring accounts were deleted, and the remaining accounts were identified by their category of cost (i.e., maintenance, operations, sustaining engineering or support), location of expenditure as well as the particular subsystems to which each account pertained. Finally, by accumulating the recurring cost accounts over common identifiers, the reduced size cost breakdown model shown in Table 1 was obtained.

The purpose of this article is to describe the procedure by which Table 1 was transformed into a subsystem cost breakdown model. As in the previous article the goal of the entire cost modeling effort is to obtain results which are accurate to within 20%.

II. Extension to a Subsystem Model

The first step in establishing costs by subsystem was to find a reasonable way of establishing percentage breakdowns with an acceptable degree of accuracy. This was done as follows:

(1) Sustaining engineering: Used percentage breakdown of the total number of Engineering Change Orders (ECR's) written in 1976 by subsystem.

(2) Maintenance: Used the average of the percentage breakdown of the work orders at GDSCC stations and Equipment Event Reports (EER's) at CMF and DMC written for a six-month period in 1976 by subsystem.

(3) Operations: Assumed that the highest activity level for operational support occurs during the countdown and therefore used the percentage breakdown of total countdown manhours by subsystem.

These percentage breakdowns are given in Table 2. Further effort is needed to improve this table. The MDS implementation will have an impact on EER, ECR and work order

percentages. Operational support percentages are being further investigated with support from DSS 14 and DSS 12.

The next step was to use the percentage breakdowns in Table 2 to spread the category costs of the COSTMODEL file (Table 1) over the set of subsystems. The following relations were used in performing this task:

$$\text{MNT COST/SS} = \left(\frac{\text{EER\%} + \text{W.O.\%}}{2}\right) \cdot \text{MNT COST}$$

$$\text{SUP COST/SS} = \left(\frac{\text{MNT COST/SS} + \text{OPS COST/SS}}{\text{MNT COST} + \text{OPS COST}}\right) \cdot \text{SUPPORT COST}$$

$$\text{SUS COST/SS} = (\text{ECR\%}) \times \text{SUS COST FOR SUBSYSTEM for system} = \text{ALL}$$

or

$$\text{SUS COST/SS} = \left(\frac{\text{ECR\%/SS}}{\text{ECR\% SUM FOR SUBSYSTEMS GIVEN IN SUBSYSTEM}}\right) \cdot \text{SUS COST}$$

$$\text{OPS COST/SS} = (\text{OPS\%/SS}) * \text{OPS COST for LOC} = \text{GDSCC; LOC} = \text{CTA; LOC} = \text{NOCC}$$

$$\text{OPS COST/SS} = \left(\frac{\text{GDSCC(MNT/SS + OPS/SS)}}{\text{GDSCC(MNT COST + OPS COST)}}\right) \cdot \text{OPS COST for LOC} = \text{SPAIN or LOC} = \text{AUST}$$

where SS = subsystem. Table 3 illustrates the resulting subsystem distribution matrix.

The next step of the procedure was to multiply the cost vectors of Table 1 by this subsystem distribution matrix. This has the effect of spreading each line item cost of Table 1 over each of its appropriate subsystems. Then the rows having common locations and categories can be combined to produce the simplified cost breakdown model of Table 4. Here we see that the number of line items has been reduced to 11 but that the column dimension has increased by the subsystem identifiers.

Finally, it is of interest to have a simplified cost breakdown model for each subsystem. To accomplish this we could simply sum each of the categories in each column of Table 4. However, the costs associated with the foreign complexes appear as a single line item in the JPL WAD. This means that the entries in Table 4 entitled AUST OPS and SPAIN OPS actually include the maintenance, operations and support costs of Australia and Spain, respectively. To separate these amounts from the total, the cost breakdowns of CTA 21 and Goldstone were examined. The examination revealed that the maintenance, operations and support costs are approximately equal. This implies that we can split the foreign line items such that one-third of the cost goes to each of these categories. After splitting these line items and summing over each of the categories we obtain the subsystem category cost model shown in Table 5.

It is important to note that there are two recurring costs associated with providing DSN service which are not included in these tables. These costs are (1) the costs associated *exclusively* with the GCF equipment at the DSN facilities and (2) the costs necessary for NASCOM relaying of signals. The exclusively GCF costs were separated from the main body of costs so that they could be handled separately; they will be added back into the cost model table at a later date. The total FY'77 amount for such accounts is $1.59 million, although the partitioning of this amount over the categories has not been accomplished. The NASCOM link costs were not included since they do not appear in the JPL WAD.

III. Conclusions

The subsystem category cost breakdown model in Table 5 is a significant step toward characterizing the manner in which DSN costs are incurred. Once the GCF, and possibly NASCOM, costs are included, the resulting model should serve as a valuable tool for comparing the economics of the present and proposed future DSN configurations.

Reference

1. Burt, R. W., and Kirkbride, H. L., "A Maintenance and Operations Cost Model for the DSN," in *The DSN Progress Report 42-38*, April 1977, pp. 109-114.

Table 1. Cost breakdown model

Item	Location	Category	Subsystems	FY'77 costs, $\$ \times 10^3$
1	AUST	OPS		4933
2	CTA	OPS	All	563
3	GDSCC	MNT	All	4349
4	GDSCC	MNT	TXR	283
5	GDSCC	OPS	All	1965
6	GDSCC	SUP	All	3792
7	JPL	MNT	All	284
8	JPL	OPS	All	673
9	JPL	SUP	All	1982
10	JPL	SUS	All	4622
11	JPL	SUS	ANT	622
12	JPL	SUS	ANT/FAC	303
13	JPL	SUS	DMC	71
14	JPL	SUS	DMC/FTS/PPR/DTT	295
15	JPL	SUS	DTK	80
16	JPL	SUS	DTK/APS	92
17	JPL	SUS	DTK/RCV/FTS	109
18	JPL	SUS	DTM	205
19	JPL	SUS	DTM/DCD	208
20	JPL	SUS	DTM/DCD/DTK/GHS/NCS	29
21	JPL	SUS	DTM/DCD/DTK/NCS/DMC/DTT/GHS/PPR/FTS	522
22	JPL	SUS	FAC	388
23	JPL	SUS	RCV	106
24	JPL	SUS	RCV/UWV/TXR	214
25	JPL	SUS	TXR	172
26	JPL	SUS	UWV	93
27	NOCC	OPS	All	2016
28	SPAIN	OPS		5076
			Grand total FY'77	34,047

Table 2. Percentage breakdowns by subsystem for various M&O activities

Subsystem	Percentage breakdown			
	ECR	EER	WO (Work Orders)	OPS (Operations)
ANT	8.0	6.7	24.6	12.0
APS	1.4	1.4	2.2	1.0
DCD	5.9	6.1	6.0	11.0
DMC	6.1	9.6	8.1	4.0
DTK	4.7	0.9	2.6	12.0
DTM	11.8	12.3	10.7	28.0
DTT	0.7	0.2	0.6	7.0
FAC	22.3	7.7	0	0
FTS	4.6	2.5	4.3	0
GCF[a] = GHS,GWB, GTY,GVC	4.3	4.8	2.0	10.0
PPR,REC,AIS	1.7	7.1	2.6	3.0
RCV	16.9	26.5	7.8	4.0
TXR	6.9	2.6	5.6	6.0
UWV	2.9	4.6	15.2	1.0
SYS[b]	2.0	7.4	8.9	0

[a]Funded by accounts not exclusively devoted to GCF, i.e., SUBSYSTEM = ALL in Table 1.

[b]System level work not attributable to one subsystem.

Table 3. Cost factor matrix

NO.[a]	LOC[a]	CAT[a]	ANT	APS	DCD	DMC	DTK	DTM	DTT	FAC	FTS	GCF	PPR	RCV	TXR	SYS	UWV
1	AUST	OPS	.14	.02	.08	.06	.07	.20	.04	.02	.02	.06	.03	.11	.05	.04	.06
2	CTA	OPS	.12	.01	.11	.04	.12	.28	.07	.00	.00	.10	.04	.04	.06	.00	.01
3	GDSCC	MNT	.16	.02	.06	.09	.02	.12	.01	.04	.03	.03	.03	.17	.04	.08	.10
4	GDSCC	MNT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00
5	GDSCC	OPS	.12	.01	.11	.04	.12	.28	.07	.00	.00	.10	.04	.04	.06	.00	.01
6	GDSCC	SUP	.14	.02	.08	.06	.07	.20	.04	.02	.02	.06	.03	.11	.05	.04	.06
7	JPL	MNT	.16	.02	.06	.09	.02	.12	.01	.04	.03	.03	.03	.17	.04	.08	.10
8	JPL	OPS	.12	.01	.11	.04	.12	.28	.07	.00	.00	.10	.04	.04	.06	.00	.01
9	JPL	SUP	.14	.02	.08	.06	.07	.20	.04	.02	.02	.06	.03	.11	.05	.04	.06
10	JPL	SUS	.08	.01	.06	.06	.05	.12	.01	.22	.05	.04	.02	.17	.07	.01	.03
11	JPL	SUS	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
12	JPL	SUS	.26	.00	.00	.00	.00	.00	.00	.74	.00	.00	.00	.00	.00	.00	.00
13	JPL	SUS	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
14	JPL	SUS	.00	.00	.00	.47	.00	.00	.05	.00	.35	.00	.13	.00	.00	.00	.00
15	JPL	SUS	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
16	JPL	SUS	.00	.23	.00	.00	.77	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
17	JPL	SUS	.00	.00	.00	.00	.18	.00	.00	.00	.18	.00	.00	.64	.00	.00	.00
18	JPL	SUS	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
19	JPL	SUS	.00	.00	.33	.00	.00	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00
20	JPL	SUS	.00	.00	.22	.00	.17	.44	.00	.00	.00	.00	.16	.00	.00	.01	.00
21	JPL	SUS	.00	.00	.15	.15	.12	.29	.00	.02	.11	.11	.04	.00	.00	.01	.00
22	JPL	SUS	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00
23	JPL	SUS	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00
24	JPL	SUS	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.63	.26	.00	.11
25	JPL	SUS	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00
26	JPL	SUS	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00
27	NOCC	OPS	.12	.01	.11	.04	.12	.28	.07	.00	.00	.10	.04	.04	.06	.00	.01
28	SPAIN	OPS	.14	.02	.08	.06	.07	.20	.04	.02	.02	.06	.03	.11	.05	.04	.06

[a]These columns bear a one-to-one correspondence with the first three columns in Table 1.

Table 4. 1977 subsystem totals by location and category

LOC	CAT	ANT 77	APS 77	DCD 77	DMC 77	DTK 77	DTM 77	DTM 77	FAC 77	FTS 77	GCF 77	PPR 77	RCV 77	TXR77	UWV77	SYS77
AUST	OPS	69	79	405	306	335	987	183	99	99	296	168	518	257	281	197
CTA	OPS	70	8	62	23	66	158	39	0	0	59	23	24	34	6	0
GDSCC	MNT	678	78	261	383	74	522	43	165	145	145	139	748	461	435	348
GDSCC	OPS	246	28	216	79	232	550	136	0	0	204	78	82	124	28	0
GDSCC	SUP	531	76	303	228	265	758	152	72	64	228	114	417	190	228	152
JPL	MNT	45	6	17	26	6	34	3	11	9	9	9	48	11	28	23
JPL	OPS	84	9	74	27	79	188	46	0	0	70	27	28	42	9	0
JPL	SUP	277	40	159	119	139	396	79	40	34	119	59	218	99	119	79
JPL	SUS	1071	86	425	572	455	1056	47	1652	396	255	144	1092	547	251	51
NOCC	OPS	252	28	222	81	238	564	139	0	0	216	81	85	127	28	0
SPAIN	OPS	711	81	416	315	345	1015	188	102	102	305	173	543	264	289	203
Totals		4656	519	2560	2159	2234	6628	1055	2141	550	1903	1015	3813	2156	1702	1053

Table 5. Subsystem/category cost model for the DSN

Category	Subsystem														
	ANT	APS	DCD	DMC	DTK	DTM	DTT	FAC	FTS	GCF[a]	PPR	RCV	TXR	UWV	SYS
Maintenance	1191	138	552	616	307	1224	170	243	222	358	262	1153	646	653	505
Operations	1119	126	848	417	842	2127	484	67	67	749	323	576	501	261	133
Sustaining	1071	86	425	572	455	1056	47	1652	396	255	144	1092	547	251	51
Support	1275	169	735	554	630	1821	354	179	165	547	286	992	462	537	364
Total	4656	519	2560	2159	2234	6228	1055	2141	850	1903	1015	3813	2156	1702	1053

[a]Does not include costs in WAD accounts which are exclusively GCF related or the NASCOM costs associated with DSN service.