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NONLINEAR MODELS FOR ESTIMATING GSFC TRAVEL REQUIREMENTS

by Charles Buffalano and Francis J. Hagan

Goddard Space Flight Center
Greenbelt, Md. 20771

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14

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16. Abstract

A methodology is presented for estimating travel requirements for a particular period of time. Travel models were generated using nonlinear regression analysis techniques on a data base of FY 72 and FY 73 information from 79 GSFC projects. Although the subject matter in this report relates to GSFC activities, the type of analysis used and the manner of selecting the relevant variables would be of interest to other NASA centers, government agencies, private corporations and, in general, any organization with a significant travel budget. Models were developed for each of six types of activity: flight projects (in-house and out-of-house); experiments on non-GSFC projects; international projects; ART/SRT, data analysis, advanced studies; tracking and data; and indirects.

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CONTENTS

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Charles Buffalano
and
Francis J. Hagan
Goddard Space Flight Center

INTRODUCTION

Resources for travel purposes are typically allocated in a discretionary manner. It is necessary, however, especially in times of decreasing budgets, to monitor the travel environment and develop a realistic estimate of requirements. This study presents a methodology for examining the travel situation and assessing the dollar requirements for a particular period of time. Although the subject matter in this report relates to GSFC activities, the type of analysis used and the manner of selecting the relevant variables would be of interest to other NASA centers, government agencies, private corporations and, in general, any organization with a significant travel budget.

Extensive travel is necessary to support the diverse activities in which GSFC is engaged. The nature of the travel is varied. The trips are related to launch support, design reviews, global tracking station management, scientific conferences and other meetings, management and coordination of programs, and travel to duty stations.

The annual process of obtaining travel money begins when NASA Headquarters provides a dollar guideline to GSFC management, who then issues a travel budget call to each of the directorates. It is the job of the directorates to carefully examine their planned efforts for the coming year and arrive at an estimate for the amount of travel money needed to support these efforts. The traditional way of accomplishing this is to use the grass roots approach. Each branch provides an estimate of the number of trips that will be required in the coming fiscal year, and their destination. An examination of the destinations and estimated durations of the trips will allow a dollar value to be calculated for the number of trips desired. These estimates are then added for all the branches within a division and all the divisions within a directorate. Each directorate then submits its request to GSFC management. Management would like to satisfy the various directorate requests so that their total is at or near the guideline. If, however, the directorates feel that more travel is needed than is allowed by the guideline, and if GSFC management agrees, then management can request, and try to justify to Headquarters, a figure greater than the guideline.

REASONS FOR EMPLOYING TRAVEL MODELS

An independent travel model estimate provides a data point that serves as input to the management decision-making process. Other inputs are the directorate estimates and GSFC management's own experience. Agreement among the inputs might strengthen faith in a decision whereas the occurrence of significant differences could point out the necessity for further examination of certain areas.

Occasionally it is necessary to respond, in a short time, to internal or Headquarters' requests for estimates of future travel requirements. An existing grass roots estimate would be limited to the immediate fiscal year and not extend any further into the future. Consequently, it would not be useful. Due to the time constraint, attempting to meet such requests by conducting a new grass roots exercise for the future time period in question would entail much intensive effort. It is also possible that the study for which the information is needed would not warrant this approach. In cases like this the travel model can be used to provide the estimates in a relatively short time.

The model can be used to experiment with different management strategies for travel. For example, management might want to determine the effect of reducing the average number of persons who travel to a launch or design review, or perhaps would like to see the effect of bringing more design reviews in-house. Both can be done by varying certain parameters in the model.

DATA BASE

The data base is composed of FY 72 and FY 73 travel information for 79 budget line items, or projects. A complete list of these projects is shown in Appendix A. These are projects to which travel expenses have been charged in the past. There are more items in the Goddard Chart of Accounts, but the efforts associated with these other projects typically do not involve travel.

In this study we have arranged these 79 projects into six subgroups according to the type of activity involved. The six types of activity are:

- Flight projects
- Experiments on non-GSFC projects
- International projects
- ART/SRT, data analysis, advanced studies
- Tracking and data
- Indirects

Appendix B shows the projects contained within each activity, along with the data (sums of FY 72 and FY 73 information) used in the modeling effort. As a result of this division, there are six separate data bases from which six models were generated.

There are several reasons for dividing the original data base into these subgroups. A single model generated from the entire data base would only yield an estimate for total GSFC travel needs. It was thought that a gross estimate such as this was not informative enough. It is important to know in what areas the money is needed, and a single overall number would not indicate this. On the other hand, generation of a separate model for each of the projects listed in Appendix A was not desired, because it would entail having a separate data base for each project. An attempt to predict travel requirements at such a specific level, with a relatively small amount of data, would be statistically unwise. Because it is becoming more common at GSFC to look at resources by type of activity, it was believed that it would be appropriate and useful to generate models at the activity level.

THE MODELS

The first step in the modeling process was to isolate factors that were believed to be related to the number of trips taken. Four were selected, namely:

- Number of launches and out-of-house design reviews
- Man-years of effort
- Cost of a trip
- Whether a flight project is in-house or out-of-house

From these factors, four independent variables were developed for use in a nonlinear, least-squares analysis. The dependent variable in the analysis was the number of trips taken. The dependent and independent variables are defined below.

T_i = number of trips taken by Project i

X_i = number of launches and out-of-house design reviews for Project i during period of interest

Y_i = budgeted man-years for Project i during period of interest

Z_i = weighting factor that incorporates an assumed inverse relationship between the cost of a trip and the number of trips taken

$$= \frac{\text{Average cost of a trip for Activity j}}{\text{Average cost of a trip for Project i}}$$

W_i = 0 or 1, depending on whether GSFC Flight Project i is conducted in an in-house or out-of-house mode

The basic form of the equation which was fit to the data was:

$$T_i = [C_1 (1 + C_2W_i) Y_i + C_3X_i] \ (Z_i)^{C_4}$$

The effect of the $C_2 W_i$ term is that there will be two models for flight projects, one for in-house and the other for out-of-house efforts. The $C_3 X_i$ term will drop out when considering the ART/SRT, tracking and data, and indirects activities. The projects that make up these activities are not directly related to any flight project and consequently are not involved with launches or design reviews. The resulting models for each activity are:

Flight Projects

In-House

$$T_i = [0.46 \ Y_i + 31.52 \ X_i] \ (Z_i)^{0.93}$$

Out-of-House

$$T_i = [2.58 \ Y_i + 31.52 \ X_i] \ (Z_i)^{0.93}$$

Experiments on Non-GSFC Projects

$$T_i = [1.45 \ Y_i + 11.11 \ X_i] \ (Z_i)^{-1.20}$$

International Projects

$$T_i = [2.12 \ Y_i + 8.99 \ X_i] \ (Z_i)^{-0.22}$$

ART/SRT Data Analysis, Advanced Studies

$$T_i = [1.52 \ Y_i] \ (Z_i)^{-0.30}$$

Tracking and Data

$$T_i = [1.20 \ Y_i] \ (Z_i)^{1.40}$$

Indirects

$$T_i = [1.22 \ Y_i] \ (Z_i)^{-0.60}$$

In order to estimate the number of trips for a given activity, the appropriate model equation must be executed for each project in the activity (according to Appendix B). The result is a series of values, T_i, which are the estimated numbers of trips for each project. Multiplying each element, T_i, by the average cost of a trip for the corresponding Project i (last column of Appendix B) yields the estimated travel dollars needed by each project. Summing these values gives the travel requirements for the activity. This procedure can be done for each of the activities and the sum of the resulting dollar values will yield a total center level cost estimate for travel.

It is interesting to note that the coefficients resulting from the regression analysis have physical significance. When the model equations are considered in terms of activity averages, (that is, ignoring the fact that they can be used to estimate travel for individual projects within the activity), the denominator of the Z term becomes the average cost of a trip for the activity, and consequently, the entire term is equal to one. In this situation, the following equation would result if the international projects model were considered as an example:

$$\text{TRIPS} = 2.12\ Y + 8.99\ X$$

The coefficient of X represents the average number of persons who attend a launch or design review. In this example approximately nine people travel to such an event for an international project. The coefficient of Y corresponds to the average number of trips, other than for design reviews and launches, that are taken per man-year of effort in this activity. Approximately two trips per man-year of effort are made for international projects. The C_4 coefficient, which is the exponent of the Z term, conveys real information of a different sort. Recall that the definition of Z accounts for a relationship between the cost of a trip and the number of trips taken. If the exponent of Z is positive, a less expensive trip will be more readily taken than a costly one, while negative values indicate that more expensive trips are more readily taken.

LIMITATIONS OF THE MODELS

There are certainly statistical limitations to these models. Since a relatively small data base was used (only 2 years of travel data), error ranges and confidence bands are difficult to interpret. Nevertheless, it is felt that the model does provide realistic estimates. The model has been used twice, and on both occasions the estimates were reasonably close to the predictions from other sources.

Two projects, Delta and Sounding Rockets, were not modeled within any activity. These were deleted from the data base, and estimates for such projects must be done on an individual basis by other means.

Any change in GSFC's basic mode of operation will not be reflected in the model result. Having used historical data, the model estimate necessarily is dependent on how things were done in the past.

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APPENDIX A
PROJECTS THAT EXPENDED MONEY FOR TRAVEL PURPOSES DURING FY 1972 AND 1973

Unique Project Number	Project Name	Unique Project Number	Project Name
13	Indirect	630	ATS
16	Health Saf	636	Air Traffic
23	Public Info	641	ERTS A/B
39	Admin Oper	680	Upper Stage
50	C of F	682	Comm ART
112	Nuclear SRT	683	Earth Obs
113	Prop + Power	684	PE
114	Mat + Struct	685	EO Adv Study
115	Space Track	757	Spacecraft PP
125	Elect SRT	770	Tech Appl
141	Tech/Util	802	MJS 77 Exp
150	T+D SRT	811	Pioneer
160	EO SRT	815	Viking
161	EO Earth Phy	819	Mariner 71
164	Comm SRT	820	Mariner 73
180	L/V SRT	821	OSO
185	PE SRT	823	Helios
186	PE Adv Dev	831	OAO
188	P+A SRT	832	HEAO
195	Lunar SRT	841	OGO
196	Planet Expt	849	Apollo App
310	T+D SRT	852	AE C/E
311	T+DA Opns	855	GEOS
312	T+DA Equip	857	SSS-A
380	T+D Spec Sup	861	IMP/AIMP
383	Lunar D/A	863	Injun
384	Planet D/A	870	UK
385	P+A Data An	871	ESRO
404	PE Inst Supt	872	ISIS
405	P+A Inst Sup	874	German Res
408	EO Inst Sup	875	Netherland
502	Aer+Sp Tech	877	RAE A/B
601	Tiros/TOS	878	SAS
604	Nimbus	894	San Marco
607	Met Sound	908	Apollo Sys
608	SMS A/B	914	Apollo Expt
610	CAS/CTS	948	Apollo App
611	GARP	975	Space Stat
613	EOS ART	996	Skylab
614	Tiros N		

APPENDIX B
FY 1972 AND 1973 DATA BASES FOR TRAVEL ACTIVITIES

Table B-1
Flight Projects

Unique Project Number	Project Name	Manpower Budget	Launches	Out-of-House Design Reviews	Trips	Total Cost ($)	Cost per Trip ($)
604	Nimbus	167	1	6	1097	142338	129
608	SMS A/B	109		2	547	207750	379
614	Tiros N	29			51	6074	119
630	ATS	323		9	966	289291	299
641	ERTS A/B	199	1	5	938	167431	178
821	OSO	207	1	1	488	183565	376
831	OAO	188	1	2	386	82225	213
852	AE C/E	209		3	1217	153413	126
855	GEOS	14			57	10217	179
857	SSS-A	58	1		60	60593	1009
861	IMP/AIMP	211	1		136	54056	397
877	RAE A/B	190	1		142	21938	154
878	SAS	199	1	3	162	58229	359

The average cost of a trip for this activity is $230.

Table B-2
Experiments on Non-GSFC Projects

Unique Project Number	Project Name	Manpower Budget	Launches	Out-of-House Design Reviews	Trips	Total Cost ($)	Cost per Trip ($)
607	Met Sound	4			14	2094	149
802	MJS 77 Exp	1			3	1080	360
811	Pioneer	12	2		56	19864	354
815	Viking	1			26	5037	193
819	Mariner 71	14			39	18995	487
820	Mariner 73	46			81	22969	283
832	HEAO	133			145	31885	219
849	Apollo App	1			1	179	179
863	Injun	1			13	1629	125
914	Apollo Expt	13			63	14054	223
948	Apollo App	3			2	601	300

The average cost of a trip for this activity is $267.

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Table B-3
International Projects

Unique Project Number	Project Name	Manpower Budget	Launches	Out-of-House Design Reviews	Trips	Total Cost ($)	Cost per Trip ($)
610	CAS/CTS	14	1	3	58	11728	202
823	Helios	87		1	199	87742	440
870	UK	21	1	2	65	29238	449
871	ESRO	1	2		1	32	32
872	ISIS	20			27	5627	208
874	German Res	14	1	3	76	49842	655
875	Netherland	10		1	43	17402	404
894	San Marco	9			2	1980	990

The average cost of a trip for this activity is $432.

Table B-4
ART/SRT, Data Analysis, Advanced Studies

Unique Project Number	Project Name	Manpower Budget	Launches	Out-of-House Design Reviews	Trips	Total Cost ($)	Cost per Trip ($)
112	Nuclear SRT	1			1	246	246
113	Prop + Power	6			18	4339	241
114	Mat + Struct	26			58	12686	218
115	Space Track	53			92	23349	253
125	Elect SRT	1			1	85	85
141	Tech/Util	6			13	992	76
150	T+D SRT	49			60	12174	202
160	EO SRT	177			347	98482	283
161	EO Earth Phy	19			23	7544	328
164	Comm SRT	60			86	13743	159
180	L/V SRT	3			5	1013	202
185	PE SRT	41			40	10141	253
186	PE Adv Dev	7			5	1067	213
188	P+A SRT	253			438	134933	308
195	Lunar SRT	32			89	19361	217
196	Planet Expt	10			2	678	339
310	T+D SRT	44			42	7081	168
383	Lunar D/A	2			3	661	220
384	Planet D/A	9			23	5252	228
385	P+A Data An	160			83	22346	269
404	PE Inst Supt	9			2	214	107
405	P+A Inst Sup	29			65	15193	233
408	EO Inst Sup	16			37	5671	153
502	Aer + Sp Tech	51			110	18694	169
601	Tiros/TOS	21			50	6551	131
611	GARP	26			161	18472	114
613	EOS ART	28			7	1571	224
636	Air Traffic	5			9	1052	116
680	Upper Stage	1			1	398	398
682	Comm ART	49			40	7375	184
683	Earth Obs	31			23	2662	115
684	PE	8			6	787	131
685	EO Adv Study	13			11	6175	561
757	Spacecraft PP	1			4	1746	436
770	Tech Appl	5			11	1551	141
841	OGO	4			1	500	500
908	Apollo SYS	3			13	1970	151
975	Space Stat	15			51	7876	154
996	Skylab	20	1		195	78972	404

The average cost of a trip for this activity is $249.

Table B-5

Tracking and Data

Unique Project Number	Project Name	Manpower Budget	Launches	Out-of-House Design Reviews	Trips	Total Cost ($)	Cost per Trip ($)
311	T+DA Opns	1022			1095	472444	431
312	T+DA Equip	476			701	240837	343
380	T+D Spec Sup	5			9	3000	333
The average cost of a trip for this activity is $397.							

Table B-6

Indirects

Unique Project Number	Project Name	Manpower Budget	Launches	Out-of-House Design Reviews	Trips	Total Cost ($)	Cost per Trip ($)
13	Indirect	33			1	301	301
16	Health Saf	25			41	14832	361
23	Public Info	28			78	26308	337
39	Admin Oper	1890			2169	450763	207
50	C of F	22			61	50890	834
The average cost of a trip for this activity is $231.							

NASA-Langley, 1974