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A CORRELATION AND FORECASTING ANALYSIS ON LOST SATELLITES

THESIS

Kenneth R. Norton

Captain, USAF

AFIT/GSO/ENS/90D-13

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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COMMITTEE:	NAME/DEPARTMENT	SIGNATURE
Advisor	Lt. Col. James N. Robinson/ENS	James N. Robinson
Reader	Major Martin R. Stytz/ENG	Martin R. Stytz

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A CORRELATION AND FORECASTING ANALYSIS
ON LOST SATELLITES

THESIS

Presented to the Faculty of the School of Engineering
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Master of Science in Space Operations

Kenneth R. Norton, B.S.
Captain, USAF

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Preface

The purpose of this study is to investigate the relationship between Space Command's Space Surveillance Center's (SSC) number of near earth lost satellites and solar activity, geomagnetic field strength, crew activity and number of sensor observations arriving into the SSC. The first task is to obtain the longest duration of data from the SSC, with the least number of gaps, to use in computations. In investigating the relationship between the number of near earth lost satellites and both solar activity and the number of sensor observations both simple and multiple regression techniques are undertaken to determine the correlation. Next multiple linear regression, time series and naive forecast 1 are used to build forecast models.

The goal of this thesis is to accomplish two things. First, because of the my prior experience in the SSC, I am very interested in learning what variables influence the number of lost satellites. Secondly, to find the best model for predicting the number of lost satellites.

In my attempt to finish this thesis I received assistance from several people to whom I am greatly indebted. First and foremost is my advisor Lieutenant Colonel Robinson. Lieutenant Colonel Robinson's understanding of space operations, his encouragement, and his ability to keep my thesis efforts focused have been key to completion of this project. Also professor Daniel Reynolds provided me with timely and insightful guidance. Finally, and definitely the most important person in my life, I must thank my wife Suzanne. I never would have finished if it were not for my wife's support and assistance.

Kenneth R. Norton

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Abstract

The relationship between the size of the United States Air Force Space Command's lost satellite lists and thirteen other variables is investigated. The thirteen variables contain the Space Surveillance Center crew's effort to work the lost list, solar activity, geomagnetic field strength, and the number of observations received each day from seven space track sensors. To identify the relationship of cause and effect between the lost lists and the thirteen variables, simple and multiple linear regressions are used on a data set that begins on 1 January 1988 and ends on 31 December 1988. Multiple linear regression and basic time-series smoothing techniques are used to forecast the number of lost satellites.

The results of this study show that solar activity causes near earth satellites to "go lost". This study also shows that not all sensors respond to increases in the size of lost lists in the same manner. Finally, the best forecast for the size of the lost satellite lists is provided by a multiple linear regression.

A CORRELATION AND FORECASTING ANALYSIS ON LOST SATELLITES

I. Introduction

Background

Out of the earth orbiting population of approximately 8,000 satellites, 6,880 are near-earth. Out of this number, an average of 50 to 75 are on the United States Space Command's (USSPACECOM) Space Surveillance Center's (SSC) near earth lost satellite list, or "lost list". This lost list, which can grow up to ten times this number in just 3 to 4 days, alarms USSPACECOM command authorities, who see the size of the lost list as evidence that the SSC's surveillance of space is incomplete. Without a complete picture of the space environment, SSC's products such as satellite decay predictions and shuttle-satellite collision information cannot be made with absolute certainty. Finding a solution to the lost list problem would greatly improve the accuracy of the satellite database information, which in turn would improve these and other products that the SSC generates.

The lost list contains all man-made satellites which have a period less than 225 minutes, have been cataloged by the SSC, and have had no sensor observations that correlate closely to their mathematical model for two or more days. The lost list is one of many outputs the SSC produces each day to accomplish its mission.

The SSC mission is to detect, track, identify, and maintain surveillance on all man-made objects in earth orbit through tasking requirements levied on a network of world wide sensors. The SSC maintains an accurate database catalog of all of these space objects and provides orbital data on them to military, civilian, and scientific agencies (3:1-11). The Space Surveillance Center (SSC), located in Cheyenne Mountain in Colorado Springs, Colorado performs the space surveillance portion of USSPACECOM's national defense mission (3:1-10).

USSPACECOM's mission is to provide an integrated command structure, comprised of the four military services, for conducting satellite tracking, satellite control and satellite launch operations. It is also responsible for providing integrated warning and assessment of attacks on the Continental U.S. by ballistic missiles, bombers, cruise missiles and space related threats. USSPACECOM provides the North American Aerospace Defense Command (NORAD) with the capability for both warning and assessment of all aerospace attacks on North America.

To accomplish its tracking mission, the SSC uses mathematical models to predict a satellite's position. These models are updated periodically. This is necessary because a satellite's orbit is constantly changing, resulting in a deviation between the true path of the satellite and its predicted orbital path. The SSC updates its predictions, using the observations from sensors, and distributes these predictions back to the Space Sensor Network (SSN). The sensors then update their data files so that they may continue to track space objects (See Figure 1).

```
                      ---------------
                     |  SPACE        |    --------------
 ------------------->|  SENSOR       |->| OBSERVATIONS |--
:                    |  NETWORK      |    --------------    :
:                     ---------------                       :
:                                                           :
:                     ---------------                       :
:    -------------   | SPACE         |                      :
 --| PREDICTIONS  |<-| SURVEILLANCE  |<---------------------
     -------------   | CENTER        |
                      ---------------
```

Figure 1. The Space Surveillance Loop

The surveillance of space requires that observations be taken at least every two days on every satellite by an SSN comprised of only twenty five sensors. To do this the SSC uses a process called selective tasking. Selective tasking involves setting each sensor's observation requirements for every satellite in order to meet SSC tasking goals. The lost list exists because the SSC has failed to meet these tasking goals.

The SSC has three tasking goals. They are: to obtain the proper number and dispersion of observations on each satellite, to ensure the most efficient use of the SSN, and to have observations on high interest satellites forwarded on a priority basis. These goals ensure the SSC will get a sufficient number of observations for all satellites. They also ensure that the number of observations received on a satellite are the proper amount given its mission and orbital parameters. Finally, these goals ensure that the observations are spread out over as much of a satellite's orbit as possible rather than clustered in one area.

Research Objective

The purpose of this research project is to test a hypothesis concerning why satellites "go lost" and to forecast the number of lost satellites. The hypothesis is that the lost list rises because of an increase in solar or geomagnetic activity or because of a decrease in the number of observations sent in by sensors or some combination of these factors. To do this, the research project attempts to find a correlation between the number of lost satellites and the following: crew activity, solar activity, geomagnetic field strength, and number of daily sensor observations sent in from seven sensors to the SSC. These correlations, are examined to determine cause and effect relationships.

The data are the result of space surveillance activity conducted in 1988. First the data variables are analyzed and explained. Then various mathematical techniques are used until either a satisfactory correlation or forecast is found, or until a conclusion that no correlation or satisfactory forecast model exists.

Overview

The remainder of this study includes a literature review of solar phenomena and geomagnetic interactions with satellites (Chapter II), data collection and description (Chapter III), methodology used to analyze the problem (Chapter IV), results of the analysis (Chapter V), and finally, conclusions and recommendations (Chapter VI).

II. Review of Literature and Background Development

Overview

The element set is fundamental to space surveillance operations. The Space Surveillance Center uses the element set to mathematically model each and every satellite's position. Each element set is comprised of six parameters which uniquely define the orbit. The element set needs to be updated periodically because a satellite's orbit is changing due to perturbations. The effects of these perturbations, which are related to solar activity, change the satellite's path through space. If this change is too sudden, sensors will either no longer be able to track the satellite or will track, but not identify, the satellite.

In this chapter three topics pertinent to this thesis are reviewed. The specific topics discussed are orbital mechanics, perturbative forces that act on a satellite's orbit, and the space sensor network.

Orbital Mechanics

Concepts and definitions of orbital mechanics necessary to understand a satellite's orbital motion about the earth are reviewed here. To completely describe each orbit, a set of parameters which uniquely defines the orbit is used. The purpose of these parameters is to discriminate one satellite from the thousands of satellites in orbit. Each unique set of parameters is called an "orbital element set". These five independent quantities called "orbital elements" are sufficient to completely describe the size, shape and orientation of a satellite's orbit. A sixth element is required to pinpoint the position of the satellite along the orbit at a particular time (1:58).

The six quantities necessary to form an element set are: right ascension of the ascending node, inclination, semi-major axis, eccentricity, argument of perigee, and time of perigee passage. Together they constitute a set of orbital elements known as a Keplerian element set (4:2-29). According to the Orbital Analyst Handbook, the Space Surveillance Center uses two quantities from the Keplerian element set to locate the orbital plane in space, two quantities to describe the size and shape of the orbit, one quantity to orient the orbit within the orbital plane, and the last quantity to locate the satellite within the orbit (3:2-5). See Figure 2.

Right ascension of the ascending node and inclination locate the orbital plane in space. Right ascension of the ascending node is an angular measurement made along the equatorial plane. The right ascension measurement starts at the vernal equinox and progresses eastward to the orbit's ascending node. The vernal equinox is the imaginary line passing from the center of the earth, through the equator, to the first point of Aries at the instant winter changes to spring. This is shown in Figure 3. The ascending node is defined as the point at which the satellite's ground trace intersects the equator as the satellite travels from the southern hemisphere into the northern hemisphere. Inclination is an angular measurement made at the ascending node. It is the angle between the equatorial plane and the orbital plane. Inclination is measured in a counterclockwise direction.

The semi-major axis describes the size of the satellite's orbit, while eccentricity describes the orbit's shape. For a near earth orbiting satellite, its orbital shape can only be circular or elliptical. The semi-major axis is one-half the longest diameter of the orbit. The longer the semi-major axis, the larger the orbit. The semi-major axis is useful to determine the period of an orbit. The period is simply the amount of time it takes the satellite to complete one orbit.

The argument of perigee orients the orbit within the orbital plane. It is an angular displacement along the orbital path, from the ascending node to perigee, measured in the direction of the satellite's motion.

Time of perigee passage locates the satellite in the orbit by specifying the last time the satellite was at its perigee. Perigee is the point in the satellite's orbit that is closest to the earth.

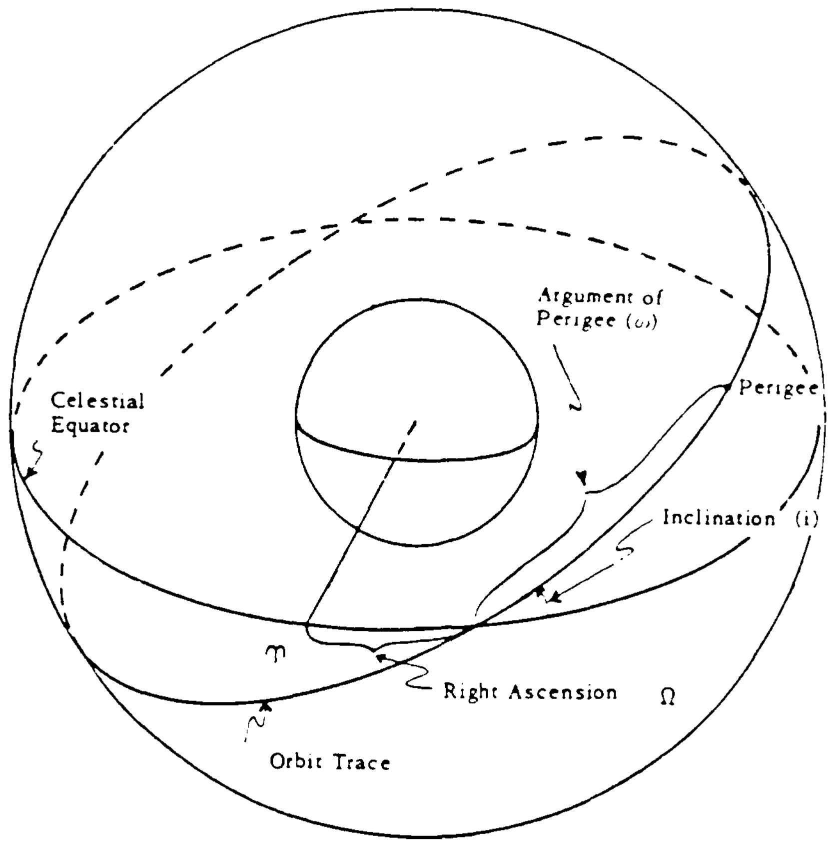

Figure 2. Orbital Elements (4:28)

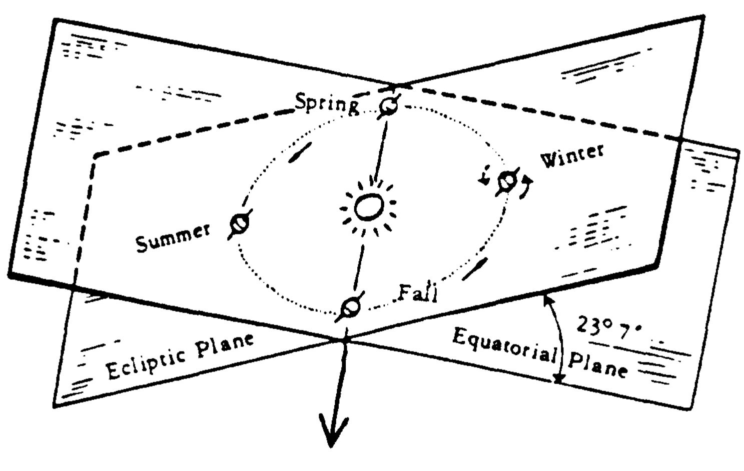

Figure 3. The Vernal Equinox (4:28)

Perturbations

A satellite's orbit is constantly changing over time because outside forces are acting upon it. The true path of the satellite will deviate from its element set's predicted orbital path because of these forces. The Space Handbook states,

> These outside forces, known as perturbations, cause deviations in the orbit from those predicted by two-body orbital mechanics. (4:2-41)

The major perturbative forces at work on satellites in near earth space are atmospheric drag, electromagnetic drag and radiation pressure. Near earth is the region above the earth's surface where a satellite's orbital period is between 87.5 minutes and 225 minutes. The near earth space environment has a higher particle density, less electromagnetic energy, and more satellites than the deep space environment.

Atmospheric drag is friction between the earth's upper atmosphere and the satellite. This drag force not only changes a satellite's orbit, but also causes the satellite to decay back to earth. Solar activity causes the upper atmosphere to expand, increasing drag. The last time "solar max" occurred, the Earth's upper atmosphere expanded enough, through the warming of ultraviolet radiation, to send 85 tons of Skylab satellite to a premature end (9:92). Solar Max occurs at the point where the highest solar activity values are recorded during the eleven year solar cycle. The second major perturbative force is radiation pressure, which is the pressure exerted on a satellite by the solar wind. The solar wind is the ever present flow of particles and ionized gases streaming outward from the sun. The particles in the solar wind stream pass the earth with velocities ranging from 400-800 km/sec on the average. Extremely large solar disturbances can result in solar wind velocities in excess of 2,300 km/sec. Consequently, radiative pressure from the sun is a major source of perturbation for satellites with large area to mass ratios (3:6-5).

Grover describes the correlation between solar activity and geosynchronous satellite orbits. He states that solar activity that is two or more standard deviations above normal will cause a substantial increase in radiation pressure. The result of this rise is anomalies in a satellite's orbit (7).

The electromagnetic perturbation on a satellite results from the satellite's motion through the Earth's magnetic field. The field produces an electromagnetic force which tries to make the satellite align itself with the magnetic field. There are two phenomena which cause the earth's magnetic field to interact with the satellite. The first is the satellite's electrical/electronic equipment sets up a magnetic field of its own. The second is the ionized gases that the satellite passes through cause electrical charges to build up on the satellite's skin (3:6-5). Grover suggests that solar activity affects the earth's magnetic field that contains all earth orbiting satellite's. He postulates that solar activity releases photons which strike molecules in the earth's upper atmosphere, liberating high energy electrons (6:64). The release of these high energy electrons strengthen the magnetic field, creating more electromagnetic drag.

Solar activity is closely related to all three of these perturbative forces. However, the relationship is not well understood (4:1-7). This uncertainty and the approach of solar max in 1991, causes physicists to again struggle with the uncertain art of solar activity forecasting in an attempt to forestall problems with other satellites (9:902).

To predict the effects of solar activity on an orbit, the Space Surveillance Center uses two solar-geophysical values, AP and F10 values, gathered by the National Oceanic and Atmospheric Administration in Boulder, Colorado. The AP value is a daily index of geomagnetic activity. It represents the degree to which the geomagnetic field varies. According to a Solar-Geophysical report, AP is an indicator of short-term changes in the earth's upper atmosphere (2:31). The F10 value is a daily solar activity observation measured at Ottawa, Canada. The F10 value rises rapidly during solar outbursts, usually optical flares. It is a good indicator of changes in solar output which cause variations in the earth's upper atmosphere. Consequently, it is frequently used as a SSC satellite modeling input to predict long-term changes in atmospheric drag (2:10). The value of these quantities categorize solar activity as being either in a quiet, unsettled, active, minor storm, major storm, or severe storm state (12:3).

Space Sensor Network

The mission of the Space Sensor Network is to maintain surveillance on all earth orbiting satellites, and to detect newly launched foreign satellites. Of the 25 sensors in the Space Sensor Network, 17 are capable of tracking near-earth satellites (3:3-4 thru 3-6).

The Space Surveillance Center utilizes the Space Sensor Network resources by tasking the sensors to take positional (metric observational) data on satellites as they pass through the sensor's coverage. The metric observations give the exact position of the satellite in relation to the radar location.

Sensors are divided up into three categories: dedicated, contributing, and collateral. A dedicated sensor is a USSPACECOM operationally controlled sensor with a primary mission of spacetrack support. A contributing sensor is a non-USSPACECOM sensor under contract by the Air Force to provide spacetrack support as requested by USSPACECOM. A collateral sensor is a USSPACECOM operationally controlled sensor that provides spacetrack support, but with a primary mission of something other than spacetrack (3:3-4). Contributing and collateral sensors provide only limited support. The collateral sensors have a primary mission of missile warning or intelligence gathering which limits spacetrack time. The contributing sensors have contract limitations which keep them from spacetracking at certain times or under certain conditions. The number of observations a sensor takes is related to it being dedicated, collateral, or contributing (11).

Phased array sensors, because of their accuracy, sensitivity, and capacity, provide more observations than mechanical trackers. Phased arrays can track multiple targets (satellites), which account for their large number of observations relative to mechanical trackers (11).

Morris believes that two sensors, the Eglin and PARCS phased arrays, contribute most of the observations needed to keep the lost list at its "normal level". This is because they are the two most sensitive sensors in the SSN. They can track satellites that other sensors simply cannot "see" (11).

Finally, KAMAN Sciences', a government contractor providing engineering and software support to the SSC, studies show that EGLIN and PARCS contribute over 31% of the total observations received daily in the Space Surveillance Center (8). If these two sensors are down for more than a day, the number of lost satellites increases. In 1989, during a four day period of high solar activity, the 2 day lost list or "attention list" soared from its normal level of about 120 lost satellites to over 1200. This is believed to be partially the result of Eglin and PARCS being unavailable during some of this period (11). Any study of the lost list must contain these two sites.

III. Data Collection and Description

Data Collection

The sensor data used in this study wa obtained from the Space Surveillance Center's database. KAMAN Sciences is the civilian contractor responsible for maintaining and upgrading software used in the SSC's Honeywell mainframe computer. The contractor uses a program named ANASAR to capture data from the computer system. The program ANASAR was written by Ford Aerospace, the original software support contractor, in 1979 when the current SSC computer system became operational. The program captures data ranging from the number of observations received from all the sensors to the number of satellites currently cataloged by the SSC. This data is kept by the company until it is briefed to USSPACECOM. The data was available through KAMAN Sciences on floppy disks, tapes and hard copy reports. It took months to find the people at KAMAN who kept the data. Data was collected over a fifteen month period with the last set arriving in September of 1990. The importance of data preparation to this study can not be overstated.

Both the data entry and verification are an important part of the data preparation process. Approximately 7,000 values needed to be assimilated and verified. The data is first converted and assimilated into an ASCII II data file in the form of a 17 by 366 matrix. Then the values are verified with hard copy printouts before use in the available mathematical processing software.

This data set is selected for two reasons. The first is that it is readily available to the SSC's operational crews. There are, for example, other indices which could be used as an indicator of solar and geomagnetic activity. However, since the SSC does not use them in its modeling techniques they are not incorporated into this study. Also, if a good predictor model can be created it must use inputs that are available to the SSC crews. A predictor model is needed so that crews can make more informed decisions about such things as whether to delay a key sensor's preventive maintenance down time, bring in more analysts or delay other computer processing jobs in an effort to keep the number of lost satellites down.

The second reason is that, based upon conversations with experienced Space Command personnel, this data set is a good sample of what accurately affects the lost list.

The daily data captured by KAMAN Sciences and used in this thesis spans 366 days starting on 1 January 1988 and ending on 31 December 1988. One day's worth of data consists of 17 fields. Four of these fields are the number of 2 day, 3 day, 4 day and more than 4 day lost satellites. Two fields refer to the SSC's Application Program 515 (AP515). Two fields are solar activity values, two are geomagnetic activity values and the remaining fields are number of observations (obs) received from seven sensors. Those sensors are Eglin, PARCS, NAVSPASUR, Otis, Beale, Robins and Eldorado. All the data used in this study is shown in Appendix A.

TABLE 1

FIELD DESCRIPTIONS

FIELD	DESCRIPTION
LOST 2	NUMBER OF SATELLITES LOST TWO DAYS
LOST 3	NUMBER OF SATELLITES LOST THREE DAYS
LOST 4	NUMBER OF SATELLITES LOST FOUR DAYS
LOST 5	NUMBER OF SATELLITES LOST FIVE OR MORE DAYS
AP LOADS	NUMBER OF TIMES AP515 RAN
AP CPU	DURATION OF AP515 RUN TIME IN COMPUTER SYSTEM
F10 BAR	SOLAR ACTIVITY VALUE
F10 ACT	SOLAR ACTIVITY VALUE
AP MAX	GEOMAGNETIC ACTIVITY VALUE
AP AVG	GEOMAGNETIC ACTIVITY VALUE
EGL	NUMBER OF OBS FROM THE SENSOR EGLIN
PAR	NUMBER OF OBS FROM THE SENSOR PARCS
NAV	NUMBER OF OBS FROM THE SENSOR NAVSPASUR
OTS	NUMBER OF OBS FROM THE SENSOR OTIS
BLE	NUMBER OF OBS FROM THE SENSOR BEALE
RBN	NUMBER OF OBS FROM THE SENSOR ROBINS
ELD	NUMBER OF OBS FROM THE SENSOR ELDORADO

Data Description

LOST SATELLITES, AP, AND F10. The LOST variable used in this study represents the number of near-earth satellites lost in a specified category that day. The LOST 2 variable refers to the number of satellites lost for 2 days, LOST 3 refers to number of satellites lost for 3 days, and LOST 4 is the number of satellites that have been lost for 4 days. The LOST 5 is different because it contains not only the number of satellites lost for 5 days, but also satellites lost for more than 5 days.

The LOST 2 and LOST 5 variables are used as the dependent variables throughout this study. These satellites are near-earth satellites cataloged by the SSC that are without observations that fully correlate to the predicted element set position within a specified time period. These numbers do not include deep space lost sateilites. The category of deep space lost satellites represent different cause and effect factors which is not relevant to this study.

The AP LOADS variable refers to the number of times the program ASSOC is run in the SSC each day, while AP CPU is the total amount of time, in seconds, that the program ran that day. This program is used by the analysts to conduct a SSC database search for observations that may fully correlate to a lost satellite. These fields indirectly represent the effort orbital analysts are putting into "finding" lost satellites. If an observation is found and it is not older than two days, it updates the element set. The satellite is then removed from the lost list. This program is on the SSC's lost list checklist. This checklist is executed three times a day as time permits.

The F10 ACT value is an average of the daily solar activity observation which is measured in Ottawa, Canada in units of 10-22 watts/meter. They are sent each day from the Solar observatory in Boulder, Colorado. The F10 BAR is a an average of the previous 90 day's worth of daily F10 ACT values. F10 values rise rapidly during solar bursts, usually optical flares. They are both good indicators of changes in the solar output which cause variations in the earth's upper atmosphere. Consequently, it is frequently used as an input to predict long term changes in atmospheric drag (2:10). The daily values follow both the 28 day and 11 year solar cycles and are associated with all observed optical flares. The SSC uses these values as an input parameter to atmospheric density models to gauge changes. These atmospheric density models are used by other programs which update a satellite's element set.

The AP values are daily indices of geomagnetic activity and are also sent to the SSC from the Solar observatory. The APAVG represents the daily average while the AP Max is the maximum recorded value for that day. They represent the degree to which the geomagnetic field strength varies. According to a Solar-Geophysical report, AP has been found to be an indicator of short-term changes in the earth's upper atmosphere (2:31). The SSC receives these values daily, from the Boulder observatory, as an input to its upper atmosphere density and satellite drag models. The following is a table showing the geomagnetic condition for various values of AP.

TABLE 2

GEOMAGNETIC FIELD CONDITIONS (12:3)

AP VALUE	CONDITION
0 - 7	Quiet
8 - 15	Unsettled
16 - 29	Active
30 - 49	Minor storm
50 - 99	Major storm
100<=	Severe storm

The values of AP used in this study are in the active condition category and represented to the SSC as the normally expected values.

SENSOR OBSERVATIONS. The space sensor network takes positional metric data or "observations" on satellites as they pass through the sensor's coverage. These daily observations give the exact position of the satellite in relation to the radar's location. The observations used in this study include all satellite category classes, all observation Association STATuses (ASTATs) and all observation types.

The SSC uses a classification system called "category classes" to prioritize satellites for the SSN to track. Through this system of categories the SSC is able to accomplish its tasking goal of using limited sensor resources to keep track of a large satellite population.

The phased array radars used in this study have three satellite categories. The lost list is made up of what the SSC categorizes as class 3 satellites. These satellites have the lowest tracking priority in near earth space. Categories (CATs) refer to the satellite's importance and resolve conflicts when two or more satellites are in a sensor's coverage at the same time and the phased array cannot track them all. Cat 1 objects are events of highest priority. Examples are new foreign launches, satellites in final stages of decay, and near earth maneuvers. Cat 2 objects are special events of high priority. Examples are deep space maneuvers, deorbits, domestic launches, special tests and projects, certain satellites in final stages of decay and SSC crew monitored satellites. Cat 3 are routine near earth satellites.

An ASTAT correlation refers to an observation's degree of association with an element set in the SSC's satellite catalog file (SATF). A sensor's observation is classified as ASTAT 1 when the observation fully associates to the position predicted by an element set in the SATF in plane, time and height. A sensor's observation is classified as ASTAT 2 when it only partially correlates to the satellite's position as predicted by an element set. ASTAT 3 or ASTAT 4 observations associate poorly or do not associate at all with any satellite's predicted position.

An "observation type" is based on how much positional data the observation provides on the satellite. Most of the observations used in this study were observation types 2, 3, or 4. These different observation types are all included as one number; the total number of daily observations sent in to the SSC from each sensor.

TABLE 3

OBSERVATION TYPES

OB TYPE	OB TYPE CONTAINS
0	Time, Range Rate
1	Time, Elevation, Azimuth
2	Time, Elevation, Azimuth, Range
3	Time, Elevation, Azimuth, Range, Range Rate
4	Time, Elevation, Azimuth, Range, Range Rate, Elevation Rate, Azimuth Rate, Range Acceleration.
5	Time, Right Ascension, Declination.
6	Time, $\dot{X}$, $\dot{Y}$, $\dot{Z}$, X, Y, Z

Table 3 shows the 7 sensors whose observations were used in this study.

TABLE 4

SPACE SENSOR SUMMARY

NAME	DATA LABEL	CATEGORY	TYPE	TRACKS
EGLIN	EGL	DEDICATED	PHASED ARRAY	DS & NE
PARCS	PAR	COLLATERAL	PHASED ARRAY	NE
NAVSPASUR	NAV	DEDICATED	CONTINUOUS	NE
OTIS	OTS	COLLATERAL	PHASED ARRAY	NE
BEALE	BLE	COLLATERAL	PHASED ARRAY	NE
ROBINS	ROB	COLLATERAL	PHASED ARRAY	NE
ELDORADO	ELD	COLLATERAL	PHASED ARRAY	NE

NE = Near Earth
DS = Deep Space

The EGL data represents the number of observations received by the SSC each day from the Eglin space track sensor. Eglin is a dedicated space track radar located in Florida's panhandle. Its exact location is 31 degrees north latitude, 274 degrees east longitude. It is a phased array sensor which can track multiple satellites at the same time. This tracker has one notable difference from the rest of the sensors used in this study. It is the only sensor that tracks both near earth and deep space objects on a regular basis.

The PAR data represents the number of observations received by the SSC each day from the Perimeter Acquisition Radar Characteristic System (PARCS) missile track sensor. PARCS is a collateral space track sensor with a primary mission of missile detection of sea launched ballistic missiles launched from the Hudson Bay. It is located in

North Dakota at 49 degrees north latitude, 262 degrees east longitude. It is a phased array sensor originally designed as part of this country's anti-ballistic missile system. Consequently it can simultaneously track very small objects.

The NAV data is the number of observations received from the SSC each day from the NAVal SPAce SURveillance center (NAVSPASUR) space track sensor. NAVSPASUR is a dedicated space track sensor using continuous array technology. It tracks any object crossing the 33rd latitude over the United States by using a system of five transmitters and three receivers. The metric information is then transmitted to the main site in Virginia for satellite correlation checks and then forwarded to the SSC.

The OTS data is the number of observations received by the SSC from the missile track sensor at Otis AFB on Cape Cod in Massachusetts. Otis is a collateral space track sensor with a primary mission of missile detection of sea launched ballistic missiles launched from the Atlantic Ocean. Its exact location is 24 degrees north latitude, 290 degrees east longitude. It is a phased array built in the 1970s which can simultaneously track multiple targets.

The BLE data is the number of observations received by the SSC from the Beale missile track sensor in California. Beale is a collateral space track sensor with a primary mission of missile detection of sea launched ballistic missiles launched from the Pacific Ocean. Its exact location is 39 degrees north latitude, 239 degrees east longitude. It is a phased array built in the 1970s which can simultaneously track multiple targets. The RBN data is the number of observations received by the SSC from the Robins missile track sensor in Georgia. Robins is a collateral space track sensor with a primary mission of missile detection of sea launched ballistic missiles launched from the Gulf of Mexico and the Atlantic Ocean. Its exact location is 30 degrees north latitude, 276 east longitude. It is a phased array built in the late 80s which can simultaneously track multiple targets.

The ELD data is the number of daily observations received by the SSC from Eldorado the missile track sensor in Texas. Eldorado is a collateral space track sensor with a primary mission of missile detection of sea launched ballistic missiles launched from the Gulf of Mexico and the Pacific Ocean. Its exact location is 30 degrees north latitude, 260 degrees east longitude. It is a phased array built in the late 80s which can simultaneously track multiple targets.

These 7 sensors out of a Space Sensor Network of 25 sensors are the only sensors used in this study. Their cumulative daily observation input represents over 80% of near earth observations received by the SSC (11).

The remaining sensors were omitted for various reasons. Some sensor sites, for example Millstone run by MIT in

Massachusetts, were left out because they tracked only deep space objects. Other sites, such as Altair in the Pacific, only tracked near earth category class 1 or 2 objects which do not make up the lost list.

Finally, any sensors that tracked only a small portion of the total near earth satellite population were left out. Shemya, a phased array sensor, located at 53 degrees north longitude, 174 degrees east latitude in the Aleutian Islands was omitted. This sensor's high longitude location prevents all low inclination satellites from being visible.

IV. METHODOLOGY

STEP 1

The first step in the analysis is to identify a strong 1 to 1 relationship between the number of lost satellites and each of the independent variables. The goal is to identify significant correlations in an attempt to identify independent variables which may cause the lost lists to change. The reverse is also of interest: independent variables which change as a result of changes in the lost lists.

Simple regression is used to fit the data to three functional relationships. The first relationship is linear and has the following form.

$$Y = a + bX \tag{1}$$

The second relationship is an exponential. Its form is:

$$Y = e^{a + bX} \tag{2}$$

The final functional form is multiplicative in the following format:

$$Y = aX^{b} \tag{3}$$

The best correlation coefficients of the simple regression correlation analysis between the number of lost satellites and each of the independent variables are used to understand lost list causation. The results of the regression are in two statistical measures; R, the correlation coefficient and an F-ratio test for significance of the correlation coefficient.

R is a parameter which measures the strength of the relationship between two sample variables (4:484). R-values range from -1 to +1. A -1 indicates a perfect linear fit with one variable decreasing while the other increases. A +1 indicates a perfect fit, with this fit having both variables either falling or rising together. R-values between -1 and +1 show a lesser degree of correlation with zero indicating no relationship.

The F-ratio determines if the results of the regression analysis are significant or due to random effects (10:155). The F-test indicates from a statistical point of view whether to use the mean or a regression relationship to describe the data. The F-test results will be shown as an "F-test Sig. Level" in the results. The correlation coefficient is significant to one minus this "F-test Sig. Level" value. The F-test Significance level used here was .10 or a 90% confidence level.

STEP 2

Multiple linear regression is used to create two combined models for the two day lost list and then two for the five day lost list. In the first combined model, the multiple regression is used to determine the combined causational effects of the independent variables. In the second combined model, the multiple regression forecasts the size of the lost list.

In each multiple linear regression a Durbin Watson (DW) value, Degrees of Freedom (DF) value, Mean Squared Error (MSE), Mean Absolute Percentage Error (MAPE) and an R-Squared value are assessed. The DW value indicates if there is autocorrelation among the residuals. The MSE value is a measure of accuracy computed by squaring the individual error for each item in the data set and then finding the average or mean value of the sum of those squares (10:689). The MSE calculation is (10:569):

$$MSE = \sum_{i=1}^{N}(X_i - F_i)^2/N \qquad (4)$$

where

X_i is the actual value

F_i is the forecast

N is the number of data values

The MAPE calculation is (10:570):

$$MAPE = \sum_{i=1}^{N} abs((X_i - F_i)*100/X_i)/N \qquad (5)$$

where

X_i is the actual value

F_i is the forecast

N is the number of data values

abs is the absolute value of

The R-Squared is the ratio of explained variance to total variance. The R-Squared calculation is (10:183):

$$\text{R-Squared} = \sum_{i=1}^{N}(Y'_i-\overline{Y})^2/\Sigma(Y_i-\overline{Y})^2 \qquad (6)$$

where

$\overline{Y}$ is the mean of Y

Y'_i is the estimated value

Y_i is the actual value

N is the number of data values

To use these results the method must satisfy the four assumptions of linearity, independence of residuals, homoscedasticity, and normality of residuals.

The linearity assumption is that the relationship between the dependent variable and independent variables is some type of linear function. Since the objective is to see if a linear fit between the dependent variable and the independent variables exists, this will be tested.

Independence of residuals assumption states that there is no time dependency among successive residuals (10:206). The DW value is used to see if this condition is satisfied. If a dependency is found, it usually indicates that the model used a nonoptimal number of independent variables, incorrect functional forms, or there are strong trends in the variables (10:206).

Multiple linear regression also assumes homoscedasticity. This is that the residual errors have the same variance over the entire range of data. This will be determined by looking at the percentage errors across all observations.

The final assumption is that the mean error terms have a normal distribution. The residuals in this study are the outcome of a large number of unimportant factors that influence the dependent variable only slightly. On the average their influence is canceled out (10:206). Because this study uses 366 days worth of data and if the other assumptions are met, then it is reasonable to assume residuals are normally distributed.

A F-test is conducted after a multiple linear model is developed and all assumptions are satisfied. This indicates whether a significant functional linear relationship exists between the dependent variable and the combined effects of the independent variables. The F-test is the ratio of the explained variance over the unexplained variance (10:185). It is tested at a confidence level of 95%. The F-test calculation is (10:160):

$$F = (r^2/(k-1))/((1-r^2)/(n-k)) \tag{7}$$

where

r is the correlation coefficient

k is the number of variables

n is the number of observations

Next t-tests at a 95% confidence interval are used to determine the significance of individual coefficients of the regression equation. This test determines whether any of the coefficients are significantly different from zero. The test, when very significant, also indicates that no serious multicollinearity exists where some independent variables are highly correlated with each other. Multicollinearity could cause erroneous regression results in the form of misleading forecasts (10:209). The hypothesized multiple linear regression equation is (10:180):

$$Y = \beta_0 + \beta_1 * X_1 + \beta_2 * X_2 + \ldots + \beta_n * X_n \qquad (8)$$

where

Y is the value of the dependent variable

β_0 is the constant of the equation

β_i is the i^{th} coefficient

X_i is the value of the i^{th} independent variable

<u>STEP 3</u>

There are two types of forecasting methods used in this study: explanatory/causal and time-series. Explanatory forecasting is done in the second half of step 2 with multiple linear regression. It assumes that there exists a cause and effect relationship between independent variables and the dependent variable. Through this relationship, changes in the independent variables affect the number of lost satellites in a predictable way. The extent of this change can be used to predict the future size of the lost list. Time-series is different from causal modeling in that it treats the system as a black box and makes no attempt to discover the factors affecting its behavior (10:15).

Time-series forecasting does not require understanding how the system operates or why changes occur. The use of a particular time-series technique assumes underlying stochastic patterns in the data such as stationarity, trend and seasonality. A data set whose mean and autocovariance structure does not depend on time is considered stationary. Trend data exhibits an increasing or decreasing behavior in the long-run. Seasonality refers to periodic patterns of the data.

In this final step, a basic time-series model will be proposed for satellites on the two and five day lost lists. The following four time-series smoothing techniques are investigated on four data sets; exponential smoothing, adaptive response rate single exponential smoothing, Holt's two parameter smoothing and Winter's seasonal smoothing. Two "model" data sets, one each for the two lost lists, will use the number of lost satellites from 5 February 1988 to 15 June 15 1988. This model data set contains 133 data points and is used to develop a time series model with each of the four methods. Two "test" data sets, one for each lost list, use the number of lost satellites from 11 July 1988 to 11 October 1988. This test set contains 93 data points and is used to check for consistency of results with the model set.

The first time-series method used is exponential smoothing. It uses a parameter, alpha (α), for weighting of both the most recent data point and the last forecasted point. This method is appropriate when there is no trend or seasonality in the data. The forecasting equation is (10:49):

$$F[t+1] = \alpha * X[t] + (1-\alpha) * F[t] \qquad (9)$$

where

F[t+1] is the next forecast

α is the inputted value between 0 and 1

X[t] is the most recent data point

F[t] is the last forecast

A high value of alpha weighs the most recent data point more than the last forecasted point, while a low value of a lowers its impact on the next forecast. It can be easily seen by substituting F[t] in the above equation with $F[t] = \alpha * X[t-1] + (1-\alpha) * F[t-1]$ that the impact of past data on the forecast decreases exponentially. The best alpha for the lost lists is obtained through trial and error using .01 increments.

Adaptive Response Rate Single Exponential Smoothing

(ARRSES) is different from exponential smoothing in that this method changes the alpha at each successive time lag. This is to respond to changes in the data pattern which make the initial alpha no longer appropriate. ARRSES also assumes that there is no trend or seasonality in the data. Alpha is set by the following equations (10:54):

$$F[t+1] = \alpha[t]*X[t] + (1-\alpha[t])*F[t] \tag{10}$$

where

$$\alpha[t+1] = abs((E[t])/(U[t])) \tag{11}$$

$$E[t] = b*(X[t]-F[t]) + (1-b)*E[t-1] \tag{12}$$

$$U[t] = b*(X[t]-F[t]) + (1-b)*U[t-1] \tag{13}$$

X[t] is the most recent data point

F[t] is the last forecast

abs is the absolute value of

b is smoothing constant set to 0.1

The third time-series is Holt's Two Parameter Smoothing and it assumes that the data has a linear trend but is otherwise stationary. This method uses two smoothing parameters, alpha (α) and beta (β), to make its forecast. The best alpha and beta for each of the four data sets are obtained through trial and error using .01 increments. The forecasted value is calculated using the following equations (10:64):

$$F[t+1] = S[t] + D[t] \tag{14}$$

where

$$S[t] = \alpha * X[t] + (1-\alpha) * (S[t-1] + D[t-1]) \quad (15)$$

$$D[t] = \beta * (S[t] - S[t-1]) + (1-\beta) * D[t-1] \quad (16)$$

F[t+1] is the next forecast

S[t] is the smoothing of the data

D[t] is the smoothing of the trend

α is a smoothing parameter

β is a smoothing parameter

The last time-series technique is Winter's seasonal smoothing. This technique assumes the data fluctuates because of stationarity, trend and seasonality. It uses three parameters to forecast, alpha (α), beta (β), and gamma (τ). The method is based on three equations, each of which smooths a parameter associated with one of the three components of pattern. Smoothing constants are between zero and one. The equations for a Winter's forecast are (10:72):

$$F[t+1] = (S[t] + D[t]) * I[t-s-1] \quad (17)$$

where

$$S[t] = \alpha * (X[t]/I[t-s]) + (1-\alpha) * (S[t-1] + D[t-1]) \quad (18)$$

$$D[t] = \beta * (S[t] - S[t-1]) + (1-\beta) * D[t-1] \quad (19)$$

$$I[t] = \tau * (X[t]/S[t]) + (1-\tau) * I[t-s] \quad (20)$$

F[t+1] is the next forecast

X[t] is the most recent data point

S[t] is the stationarity at time t

D[t] is the trend at time t

I[t] is the seasonal index at time t.

α is a smoothing parameter

β is a smoothing parameter

τ is a smoothing parameter

MODEL COMPARING

It is useful to use a different forecasting method called the Naive Forecast 1 (NF1) as a basis in evaluating other methods in a given data set. This method uses as a forecast the most recent information available in forecasting the actual value (10:570). It simply uses the number of lost satellites today as the prediction for the number of lost satellites tomorrow.

V. Results of Analysis

Simple Regression Causation Analysis

The results shown in Table 5 are from the best simple regression models fit with the 17 independent variables against both the two and five day lost variables, LOST 2 and LOST 5. All three model fits were tested, but in all cases, the best fit is obtained with a linear model as opposed to the exponential or multiplicative models.

TABLE 5

ONE-TO-ONE LINEAR REGRESSION RESULTS
OF THE 2 AND 5 DAY LOST LISTS

INDEPENDENT VARIABLE	2 DAY CORRELATION COEFFICIENT	2 DAY F-TEST SIG. LEVEL	5 DAY CORRELATION COEFFICIENT	5 DAY F-TEST SIG. LEVEL
LOST 2	1	.00000	.356927	.00000
LOST 3	.524740	.00000	.417252	.00000
LOST 4	.375023	.00000	.463404	.00000
LOST 5	.356927	.00000	1	.00000
AP LOADS	.145691	.00582	.223495	.00002
AP CPU	-.067550	.20291	.016414	.75727
F10 BAR	.217645	.00003	.248148	.00000
F10 ACT	.229773	.00001	.274434	.00000
AP MAX	-.096120	.06968	-.030506	.56563
AP AVG	-.111751	.03480	-.061169	.24900
EGL	.088532	.09535	.348468	.00000
PAR	.003015	.95480	.130995	.01338
NAV	.067486	.20334	.185268	.00043
OTS	-.080404	.12998	-.009359	.86031
BLE	.073319	.16687	-.027681	.60217
RBN	-.090277	.08853	-.080115	.13083
ELD	.094899	.07332	.178322	.00071

The first four rows of Table 5 show that the LOST variables highly correlated with each other. These correlations are as expected.

The other correlations in Table 5 do not necessarily imply causation. To properly analyze correlations for cause and effect relationship, the space surveillance process being examined must be kept in mind. In light of that process, these correlations show some interesting as well as surprising results.

The AP LOADS and AP CPU correlations give conflicting indications for the two day lost list. They both show a weak negative correlation with opposite results. The AP CPU correlation coefficient is not significant. The AP LOADS is significant and indicates that changes in the two day lost list are correlated with, and therefore may be attributed to crew activity. Results for the five day lost list are different. The AP LOADS and AP CPU correlations are positive, however only AP LOADS, is significant positive. It is irrational to believe that as the crews work more, the five day lost list rises. It is more likely that as the five day list rises, crew activity increases to control the number and reduce the lost satellite list.

The F10 ACT and F10 BAR solar index values have strong significant positive correlations with both lost lists. This indicates that as optical flares increase, the number of lost satellites increases in the LOST 2 and LOST 5 categories. This correlation is logical because solar activity is known to affect satellite's orbits. The geomagnetic activity did not correlate very well with either the two or five day lost list. The correlations were all negative instead of the expected positive. Only the two day lost list geomagnetic correlations are significant. They indicate that the geomagnetic field strength does not affect a satellite's orbit enough to contribute to it "going lost". This is a surprising result since it was originally believed, through conversations with Space Command analysts, that this would be a factor in satellite's "going lost".

The analysis of the plots of dependent variables LOST 2 and LOST 5 versus the independent variable F10 ACT reveals some interesting points.

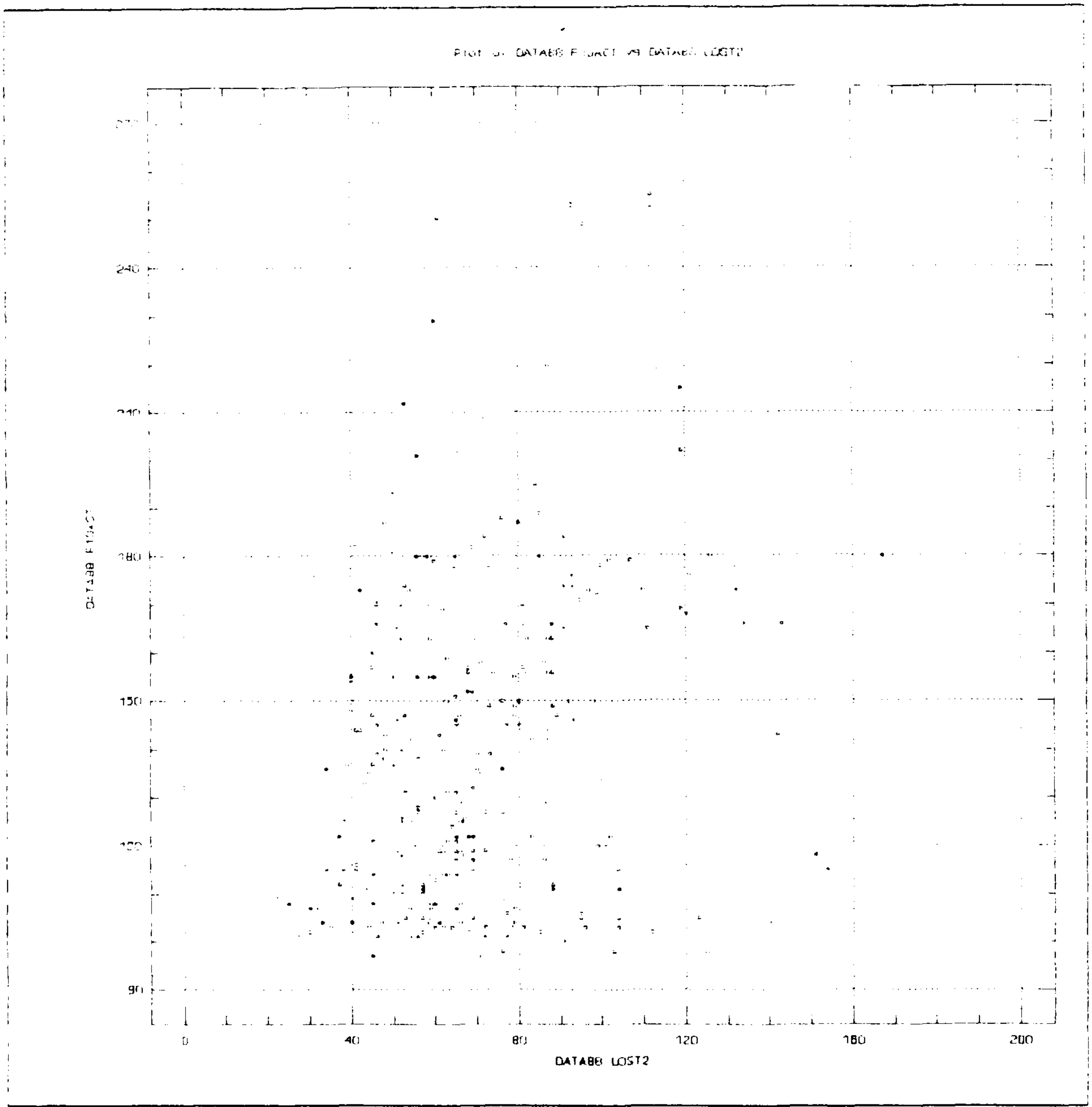

Figure 4. 2 Day VS F10 ACT

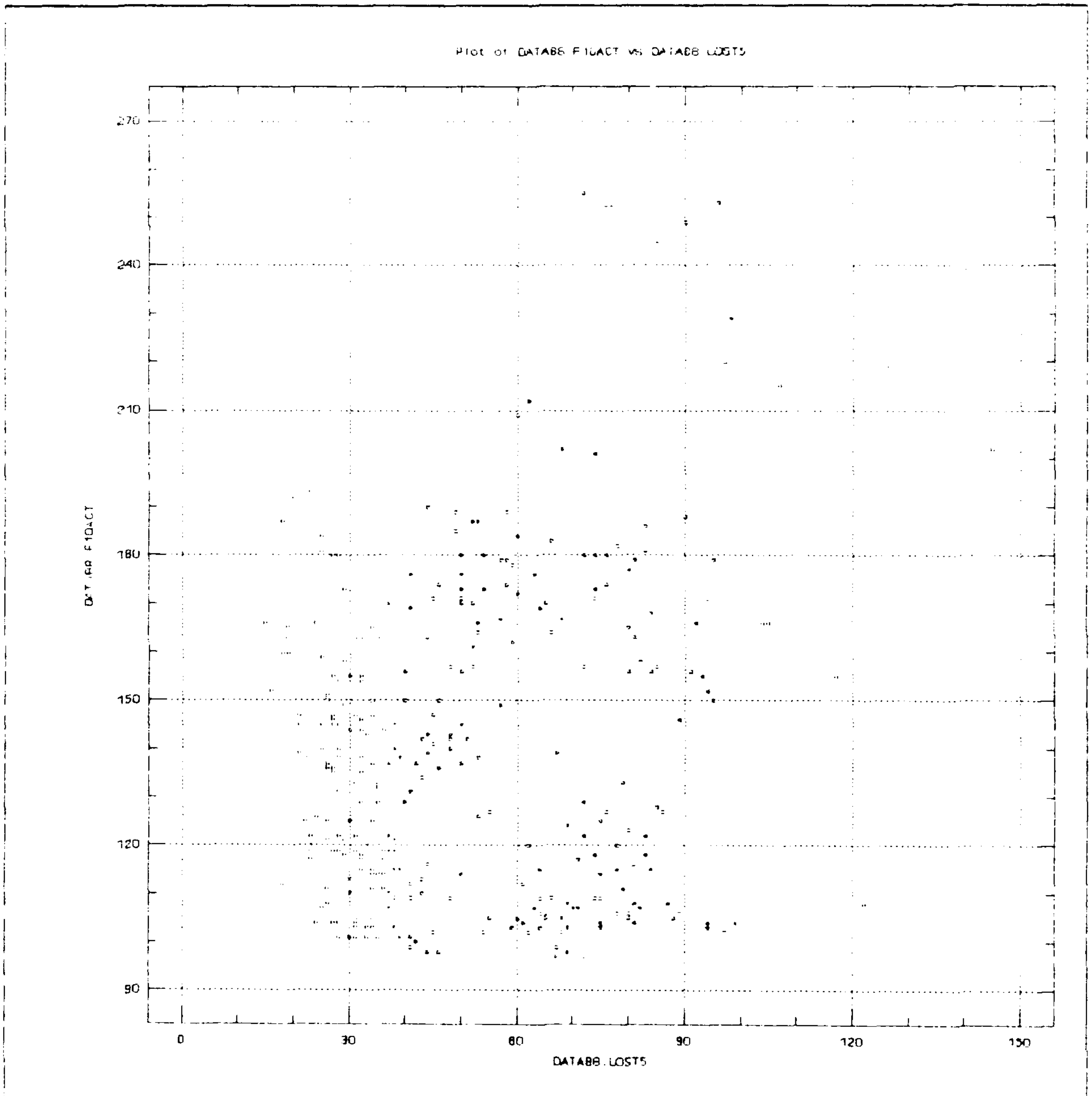

Figure 5. 5 Day VS F10 ACT

The two plots show a lack of points in the upper left and lower right corners. This lack of points in the opposite extremes indicate that low solar activity does not coincide with a high number of lost satellites or vice versa. The high density of points in the lower left and upper right corners of the plots show that low solar activity corresponds to a low number of lost satellites and that high solar events correspond to a high number of lost satellites. This trend indicates that solar activity does have some ability, though apparently small, to affect the two and five day lost lists. The middle lower portion of the plots where the lost lists increase without an increase in solar activity are perhaps increases caused by other variables.

The sensor correlation data showed both positive and negative correlations. The strongest correlations were on the five day list with Eglin, PARCS, NAVSPASUR, and Eldorado. All of these correlations were positive and significant. This indicates that as the five day list increases, these sensors are sending in more observations. On the two day list, the correlations were positive significant for Eglin and Eldorado, while negative significant for Robins. The variables are examined further by lagging.

Lagging the independent variables provides more information on causation between the dependent and independent variables. This procedure is useful in determining whether a lost list change triggers an independent variable change or if a change in an independent variable causes the lost list to change. This lagging procedure would also be useful in identifying any time delays between changes in the lost lists in relation to each of the dependent variables.

An independent variable that has positive lag is using a past value to compare to the present lost list value. A negative lag uses a future value to compare against the present lost list number. All lag values are in days. Exponential and multiplicative models are attempted as well as a linear model to determine the best model fit. As before, the linear models are the best fit for the lagged values. The "best" lag factor is one which, using trial and error, produced the highest absolute correlation coefficient.

TABLE 6

ONE-TO-ONE LINEAR REGRESSION RESULTS
OF THE 2 DAY LOST LIST WITH BEST LAG VALUES

INDEPENDENT VARIABLE	2 DAY CORRELATION COEFFICIENT	BEST LAG	F-TEST SIG. LEVEL
LOST 3	.718589	-1	.00000
LOST 4	.552985	-2	.00000
LOST 5	.446662	-3	.00000
AP LOADS	.222735	-1	.00002
AP CPU	.088172	-4	.09862
F10 BAR	.221176	-3	.00003
F10 ACT	.229773	0	.00001
AP MAX	-.137976	-1	.00914
AP AVG	-.159977	-1	.00247
EGL	.221495	-4	.00003
PAR	.096515	-2	.06972
NAV	.097130	-2	.06756
OTS	-.080404	0	.12998

TABLE 6 (cont)

ONE-TO-ONE LINEAR REGRESSION RESULTS
OF THE 2 DAY LOST WITH BEST LAG VALUES

INDEPENDENT VARIABLE	2 DAY CORRELATION COEFFICIENT	BEST LAG	F-TEST SIG. LEVEL
BLE	.073319	0	.16687
RBN	-.090277	0	.08853
ELD	.094899	0	.07332

The above correlations clarify the cause and effect relationship first shown in Table 5. The independent variables LOST are highly correlated with the two day lost list. These strong correlations identify a lag that shows a rise in the two day lost list today causing the greatest increase in the three day lost list tomorrow. It also causes an increase in the four day lost list two days from now, and an increase in the five day lost list three days from now.

The first four rows of Table 6 also approximately reflect the percentage of satellites on the two day lost list that end up on the other lost lists. About 72% of the two day lost satellites will not be found within the first day. These satellites will progress to the three day lost list. The table also shows that about 55% of the two day lost list will not be found within the first two days, and about 45% will not be found within three days.

The AP LOADS and AP CPU have strong significant positive correlations, one and four days, respectfully, after the two day lost list increases. The correlation with the AP LOADS is strongest a negative one lag indicating that the crews work the lost list one day after it increases.

The F10 BAR and F10 ACT have strong significant positive correlations. The F10 BAR correlates highest three days after the two day lost list because it is a ninety day rolling average of F10 ACT daily values and so does not respond to F10 ACT changes quickly. The F10 ACT had zero lag indicating that optical flares have an immediate effect on the two day lost list.

The AP MAX and AP AVG negative significant correlations indicate that the geomagnetic field strength does not affect the two day lost list. If the geomagnetic field strength is a factor, it should have a positive, not negative, correlation.

The sensor correlations using the lag procedure show two important points. First, the two day lost list does not rise because of a decrease in observations from any sensor. If it did, it would have be expected to observe a negative correlation with a positive lag factor. Instead, the sensors have positive significant correlation with negative lags with three sensors: Eglin, PARCS and NAVSPASUR. The lags were -2 to -4 indicating that these sensors increased the number of observations they send in two to four days after the two day lost list increases. Comparing these results with Table 5, Eglin's correlation increased from .008532 to .221495, PARCS from .003015 to .096515, and .067486 to .097130 from NAVSPASUR. The second discovery is that Otis, Beale, Eldorado and Robbins do not affect, and do not respond to, the two day list rising.

TABLE 7

ONE-TO-ONE LINEAR REGRESSION RESULTS
OF 5 DAY LOST LIST WITH BEST LAG VALUES

INDEPENDENT VARIABLE	5 DAY CORRELATION COEFFICIENT	BEST LAG	F-TEST SIG. LEVEL
LOST2	.446662	3	.00000
LOST3	.510975	2	.00000
LOST4	.574658	1	.00000
AP LOADS	.271936	-2	.00000
AP CPU	.142695	-4	.00733
F10 BAR	.248148	0	.00000
F10 ACT	.277635	-1	.00000
AP MAX	-.165492	-11	.00201
AP AVG	-.16011	3	.00250
EGL	.367112	-1	.00000
PAR	.152675	-1	.00393
NAV	.208379	-1	.00007
OTS	-.009359	0	.86031
BLE	-.027681	0	.60217
RBN	-.080115	0	.13083
ELD	.196402	-1	.00071

The correlations in Table 7 are between the five day lost list and each of the independent variables with the lag that resulted in the highest correlation coefficient. All the LOST independent variables highly correlated, as expected, with the five day lost list. The best lag factors found through trial and error made sense: for example, the present day five day lost list correlates best with the two day lost list three days earlier. These strong correlations mean that a rise in the two day, three day, and four day lost lists "causes" the five day lost list to increase. This correlation was expected.

The first four rows of Table 7 show the percentage of satellites on the other lost satellite lists that end up on the lost five day list. The table shows that about 45% of the two day lost satellite list will stay lost for three more days, about 51% of the three day lost satellite list stay lost for two more days, and at least 57% percent of the four day lost satellites list will stay lost at least one more day.

The AP LOADS and AP CPU have their strongest significant positive correlation two and four days respectfully after the five day lost list increases. The correlation with the AP LOADS is strongest at a negative two lag indicating that the crews work the lost list two days more after it increases. The AP CPU's greatest increase is four days after the lost five day list increases. This is different than the results found on the two day lagged correlation analysis.

The F10 BAR and F10 ACT have strong significant positive correlations. The F10 BAR variable with no lag (same day) best correlates with the five day lost list. The F10 ACT had negative lag indicating that optical flares the day after have the greatest effect on the five day lost list.

Since the five day lost lists consists of satellites lost for five days or more, this negative lag is as expected.

The AP MAX and AP AVG have negative significant correlations, as with the two day lost list, indicating that the geomagnetic field strength does not affect the five day lost list. If the geomagnetic field strength was a factor, it should have a positive, not negative correlation.

The sensor correlations using the five day lost list and lag procedure showed some differences from the two day lag analysis. Eglin, PARCS and NAVSPASUR start sending in more observations just as they did for the two day list except the maximum correlation for all of them occurs one day after the five day lost list increases. These three sensors also had stronger correlation coefficients than the two day list indicating that they are more responsive to five day lost list changes than two day lost list changes. Strong correlations with the five day lost list also included Eldorado as a sensor that responds to changes in the lost list. However, for the two day lost list, Eldorado had only a .094899 correlation with lag zero. For the five day list it showed .196402 with a negative lag of one. This indicates that Eldorado may respond slightly to changes in the five day lost list. The remaining sensors' correlations were not significant.

Multiple Regression Causation Analysis

A stepwise variable selection procedure on the software package Statgraphics is used to perform the multiple linear regression. A stepwise assessment on an independent variable entering into the model is done by conducting an F-ratio test of 4.0 for a 95% confidence interval. By using the F-ratio test, the stepwise selection technique rejects independent variables which do not, in combination with other variables, add significance to the overall relationship. The goal of this procedure is to combine the causational effects of all the independent variables identified in the simple linear regression into one relationship. It is a goal to determine if an optimal mix of the independent variables can together explain a large portion of the variation in the lost satellite list.

TABLE 8

MULTIPLE LINEAR REGRESSION NO TRANSFORMATION
FOR CAUSATION OF THE 2 DAY LOST LIST

Independent Variable Added	BEST LAG	Cumulative R-Squared Value
F10 ACT	0	.05280

DW = .987
DF = 355
MSE = 646.828
R-Squared(ADJ)= .05013

Table 8 shows the results of using the best positive or zero lag with no transformation of variables on the two day lost list. The two independent variables are used F10 BAR and F10 ACT. The stepwise selection technique rejects the F10 BAR because it did not add significantly in combination with F10 ACT to explain the lost 2 day lost list variance. The results of the multiple regression are suspect because the Durbin-Watson value was .987 implying that there is a violation of the independence of residuals assumption. This means that the R-Squared(ADJ) could be incorrect. To improve the DW value a Log transformation is used.

The results of the log transformation are shown in Table 9. The DW value got worse after this transformation. The next transformation is the method of first differences.

TABLE 9

MULTIPLE LINEAR REGRESSION LOG TRANSFORMATION FOR CAUSATION OF THE 2 DAY LOST LIST

Independent Variable Added	BEST LAG	Cumulative R-Squared Value
F10 ACT	0	.05218

DW = .389
DF = 355
MSE = .115716
R-Squared(ADJ)= .04951

TABLE 10

MULTIPLE LINEAR REGRESSION DIFFERENCE TRANSFORMATION
FOR CAUSATION OF THE 2 DAY LOST LIST

Independent Variable Added	BEST LAG	Cumulative R-Squared Value
F10 ACT	0	.01433

DW = 2.406
DF = 349
MSE = 635.746
R-Squared(ADJ)= .01151

The method of first differences results in a DW value of 2.406, so it can be concluded that this relationship has less autocorrelation of residuals. The R-Squared value was only .01151. This means that the multiple linear regression with a difference transformation does not explain more variance than the simple linear regression.

TABLE 11

MULTIPLE LINEAR REGRESSION NO TRANSFORMATION
FOR CAUSATION OF THE 5 DAY LOST LIST

Independent Variable Added	BEST LAG	Cumulative R-Squared Value	t-values
LOST 4	1	.32317	7.8430
LOST 2	3	.34643	3.3763
F10 ACT	0	.36302	2.9539

DW = .396
DF = 335
MSE = 416.749
R-Squared(ADJ)= .35732

Table 11 shows the results of using the best positive or zero lag with no transformation of variables on the five day lost list. The five independent variables used are LOST 2, LOST 3, LOST 4, F10 BAR and F10 ACT. For the five day lost list the stepwise selection technique rejected LOST 3 AND the F10 BAR because they did not add significance to the relationship. The results of this multiple regression are suspect because of a Durbin-Watson value of only .396 implying that there is autocorrelation among the residuals. To improve the DW value a Log transformation is used.

The results of the multiple linear regression with log transformations of the variables are shown in Table 12.

TABLE 12

MULTIPLE LINEAR REGRESSION LOG TRANSFORMATION FOR CAUSATION OF THE 5 DAY LOST LIST

Independent Variable Added	BEST LAG	Cumulative R-Squared Value	t-values
LOST 4	1	.26287	7.2807
LOST 2	3	.29281	3.7710

DW = .363
DF = 336
MSE = .167862
R-Squared(ADJ)= .28860

The DW value got worse after this transformation. The next transformation attempted is the method of first differences.

TABLE 13

MULTIPLE LINEAR REGRESSION DIFFERENCE TRANSFORMATION
FOR CAUSATION OF THE 5 DAY LOST LIST

Independent Variable Added	BEST LAG	Cumulative R-Squared Value	t-values
LOST 4	1	.19183	9.5369
LOST 3	0	.23940	4.5428

DW = 1.939
DF = 330
MSE = 72.2325
R-Squared(ADJ)= .23479

The method of first differences results in a DW value of 1.939, so it can be concluded that this relationship has little or no autocorrelation of residuals. The R-Squared value is only .23940. This means that the multiple linear regression with a difference transformation does not explain more variance than the simple linear regression with the LOST 4 variable. The author reran simple linear regression using the method of first differences on LOST 4 for comparison, however the results were not significant.

Multiple Regression Forecasting Model

The stepwise variable selection procedure on the software package Statgraphics that is used to perform the multiple linear regression for causation analysis is also used for forecasting. The same F-ratio test of 4.0 for a 95% confidence interval was conducted to determine which independent variable would enter the model. The goal of this procedure is to combine into one relationship all the independent variables identified in the simple linear regression as strongly correlated to changes in a lost list. Only positive lags, including zero, are used since the author is only interested in using values that are available at the time of the prediction. For example, a lag of -1 is not used since it refers to tomorrow's value of a particular variable. The author wants to know if an optimal mix of the independent variables can significantly forecast the number of lost satellite's one day ahead.

The results of the regression are in Table 14. These results use the best positive or zero lag with no transformation of variables. The results of this multiple regression are not suspect since none of the assumptions are violated.

TABLE 14

2 DAY LOST LIST PREDICTOR

Independent Variable Added	BEST POS LAG	Cumulative R-Squared Value	Coefficient	t-values
LOST 2	1	.27894	.417428	8.9126
EGL	1	.30937	-.003665	-7.3204
LOST 5	1	.34436	.193356	3.7509
F10 BAR	1	.37049	.209761	2.6830
LOST 4	1	.38747	-.348083	-2.7245
BLE	1	.40196	.007539	3.2477
ELD	1	.41290	.011050	3.6273
RBN	1	.42208	-.006994	-2.7880
F10 ACT	1	.43337	.141076	2.5959

TABLE 14 (cont)

2 DAY LOST LIST PREDICTOR

CONSTANT = -.341589
DW = 1.939
DF = 341
MSE = 390.207
MAPE = 20.3355
R-Squared(ADJ)= .4183

The adjusted R-Squared of .4183 indicates that this regression relationship explains 41.83% of the total variation in the two day lost list. The multiple linear regression MSE is 390.207 with a MAPE of 20.335, compares well with a NF1 method of MSE of 641.3704 and a MAPE of 27.263

TABLE 15

5 DAY LOST LIST PREDICTOR

Independent Variable Added	BEST POS LAG	Cumulative R-Squared Value	Coefficient	t-values
LOST 5	1	.86722	.858838	42.7273
LOST 4	1	.88995	.841187	9.3709
LOST 3	2	.89743	-.267703	-4.9719

CONSTANT = 3.14624
DW = 1.8
DF = 339
MSE = 68.9474
MAPE = 10.59243
R-Squared(ADJ)= .89652

The results of the multiple linear regression forecast for the five day lost list are in Table 15. The results also use the best positive or zero lag with no transformation of variables. The results are not suspect since none of the assumptions are violated. This means that the multiple linear regression with an MSE of 68.9474, MAPE of 10.592 and an adjusted R-Squared of .89652 indicates that this regression relationship explains 89.65% of the total variation in the five day lost list. The NF1 method has good but not better results. NF1 has a MSE of 92.350 and a MAPE of 12.809 for the five day lost list.

Time Series Forecasters

The following figures show the fluctuation of each of the lost lists through the two periods used for time series forecasting. The model set is from February 5 to June 15, 1988 and the test set is from July 11 to October 11, 1988. Only the two day lost list model set shows no trend in the data, while among the other three, only the five day model set trends downward.

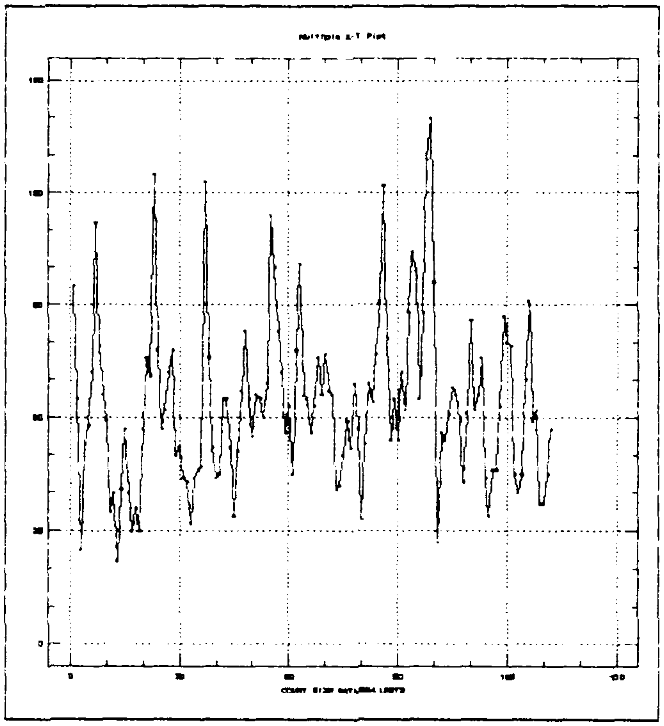

Figure 6. 2 Day Lost List Model Set

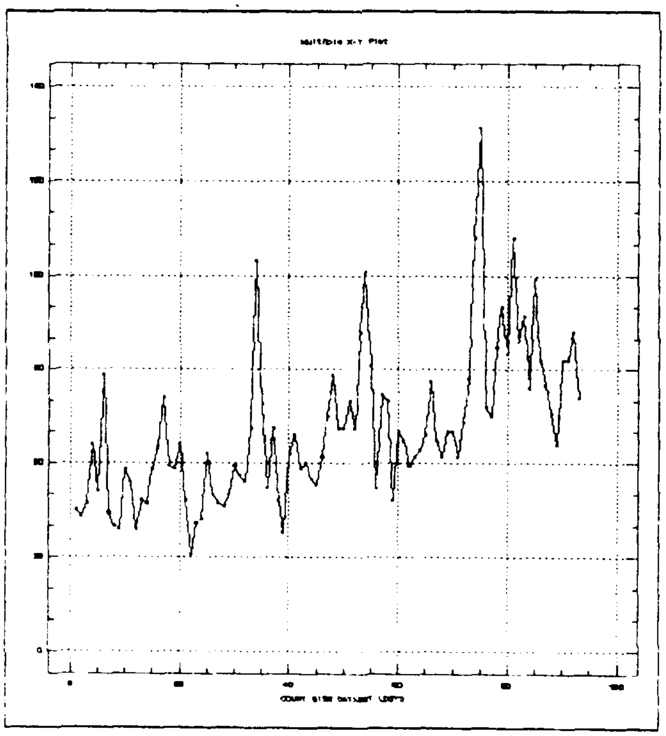

Figure 7. 2 Day Lost List Test Set

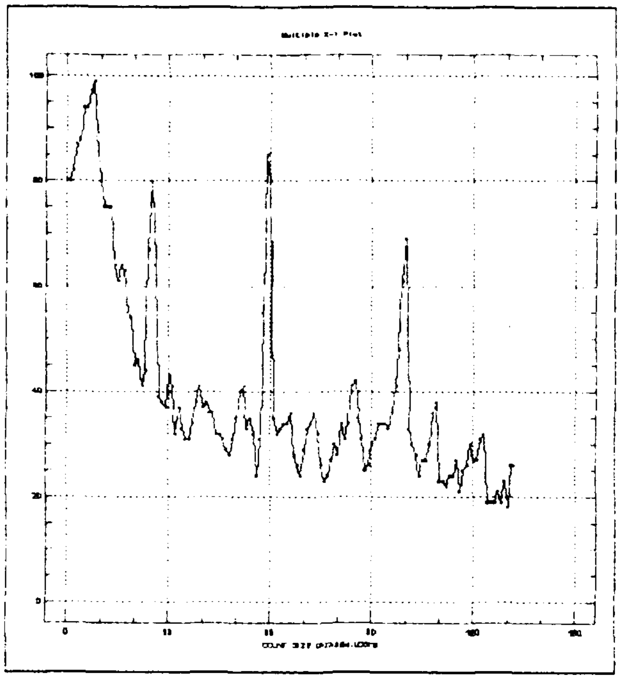

Figure 8. 5 Day Lost
List Model Set

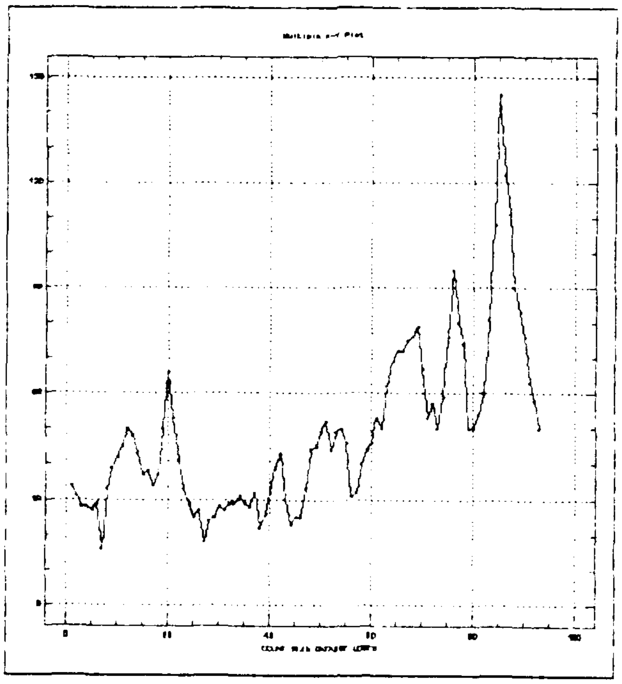

Figure 9. 5 Day Lost
List Test Set

TABLE 16

EXPONENTIAL LINEAR SMOOTHING RESULTS

α	MSE	MAPE	LOST LIST	DATA SET
.12	530.518	30.2345	2 DAY *	MODEL
.12	406.547	19.8260	2 DAY	TEST
.05	396.228	18.8220	2 DAY *	TEST
.68	99.014	16.7959	5 DAY *	MODEL
.68	122.830	17.2058	5 DAY	TEST
.77	119.945	16.8142	5 DAY *	TEST

* BEST RESULTS FOR THAT LOST LIST DATA SET

The results of the exponential smoothing on the two and five day lost lists are shown in Table 16. The "best" alpha, found through trial and error using .01 increments, is the one that has the lowest MSE for that set of data. First the best alpha is found for the model set. Then that alpha is used on the test set to check for consistency of results. Finally a "best" alpha is found for the test set. This method did not provide better MSEs than the multiple linear regression model.

For the two day lost list, exponential smoothing uses low alpha values indicating these predictions are more dependent on the last forecast rather than the most recent data point when making the next forecast. This is because the relationship is:

$$F[t+1] = \alpha * X[t] + (1-\alpha) * F[t] \tag{21}$$

where

F[t+1] is the next forecast

α is the inputted value between 0 and 1

X[t] is the most recent data point

F[t] is the last forecast

The results show the two day lost list is not as dependent on the previous values as much as the five day lost list. The five day lost list has the smallest MSE when the alpha rose to .68 for the model set and .77 for the test set. The size of the five day lost list is more a function of the previous day's size than any forecasted change.

TABLE 17

ADAPTIVE RESPONSE RATE EXPONENTIAL SMOOTHING RESULTS

MSE	MAPE	LOST LIST	DATA SET
571.736	31.255	2 DAY	MODEL
509.134	23.398	2 DAY	TEST
139.193	19.959	5 DAY	MODEL
254.019	21.151	5 DAY	TEST

The adaptive response rate exponential smoothing using an adjustable alpha had MSEs that are higher than the MSEs of the exponential smoothing which used fixed alphas. The higher MSEs are shown in Table 17. The present alpha is adjusted based on the error of the last forecast as well as to past adjustments made to the alpha. The failure of the adjustable alpha to forecast the data set as well as the fixed alpha is due to the fact that it weights more of the past changes it goes to predict changes in the lost lists.

The exponential smoothing models provide forecasts based on the assumption that the data is level. If the data is also trending, the exponential forecasts have a greater MSE than a technique, such as Holt's two-parameter smoothing, which takes into account a trend in the data. The results of Holt's two parameter smoothing are shown in Table 18.

TABLE 18

HOLT'S SMOOTHING RESULTS

α	β	MSE	MAPE	LOST LIST	DATA SET
.98	.09	544.832	29.3974	2 DAY *	MODEL
.98	.09	494.567	22.9716	2 DAY	TEST
.37	.03	400.504	19.5392	2 DAY *	TEST
.99	.02	71.705	13.4111	5 DAY *	MODEL
.99	.02	104.084	16.1095	5 DAY	TEST
.99	.03	103.997	15.9464	5 DAY *	TEST

* BEST RESULTS FOR THAT LOST LIST DATA SET

The alphas and betas that resulted in the lowest MSE for each set of data are shown. The alphas and betas in the table are found through trial and error using .01 increments.

The results of Holt's method on the two day list are no better than results obtained by exponential smoothing. Holt's MSE for the two day model set is 544.832 while the exponential is 530.518. The best MSE for the two day test set is 400.504 using Holt's method, and 396.228 using exponential smoothing. The two day data sets exhibit little or no trend changes.

The MSEs for the five day lost lists were better using Holt's method than using exponential smoothing. The MSE went from 99.014 down to 71.705 for the five day model set when trending in the data is accounted for. The five day test set's MSE also decreased from 119.945 with exponential smoothing down to 103.997 with Holt's method.

Holt's two parameter smoothing takes into account only stationarity and trends in the data sets. If seasonality is also at work at changing the data pattern, then Winter's seasonal smoothing method should provide better results.

The results of Winter's seasonal smoothing are shown in Table 19. The alphas, betas, gammas and length of seasonality resulted in the lowest MSE for that set of data. The smoothing parameters in the table were found through trial and error using .01 increments. The length of seasonality is also found through trial and error with one day increments.

TABLE 19

WINTER'S SEASONAL SMOOTHING RESULTS

α	β	τ	LENGTH OF SEASON	MSE	MAPE	LOST LIST	DATA SET
.66	.01	.99	28	584.264	31.4983	2 DAY *	MODEL
.66	.01	.99	28	625.709	26.5010	2 DAY	TEST
.35	.03	.01	2	406.390	19.5350	2 DAY *	TEST
.99	.02	.01	2	72.195	13.4882	5 DAY *	MODEL
.99	.02	.01	2	105.255	16.2877	5 DAY	TEST
.99	.03	.01	2	105.168	16.1228	5 DAY *	TEST

* BEST RESULTS FOR THAT LOST LIST DATA SET

Winter's seasonal smoothing technique results are not better in MSE or MAPE than Holt's. Winter's MSE for the two day model set was 584.264 while Holt's MSE was 544.832. The MSE for the two day test set was 406.390 using Winter's and 400.504 using Holt's method.

The five day model lost list MSE using Winter's method was 72.195, for Holt's it was 71.705. The five day lost list test set had an MSE of 105.168 using Winter's method but 103.997 using Holt's method.

Table 20 shows the results of the NF1 method for both the two and five day lost lists over the model and test sets.

TABLE 20

NAIVE FORECAST 1 RESULTS

LOST LIST	DATA SET	MSE	MAPE
2 DAY	MODEL	468.275	28.6017
2 DAY	TEST	452.696	21.9035
5 DAY	MODEL	68.412	12.9964
5 DAY	TEST	97.848	15.2106

The NF1 provided better results than any time series model for the two day lost model set, five day model set and the five day test set. On the two day test set Exponential smoothing still has the best results with an MSE of 396.228 compares with NF1's MSE of 452.696.

Table 21 is a summary of all the forecasting methods results on the two day lost list.

TABLE 21

SUMMARY OF 2 DAY LOST LIST FORECAST METHODS

DATA SET	METHOD	MSE	MAPE
MODEL	EXPON	530.518	30.234
MODEL	ARRES	571.736	31.255
MODEL	HOLT'S	544.832	29.397
MODEL	WINTER'S	584.264	31.498
MODEL	NF1	468.275	28.601
TEST	EXPON	396.228	18.822

TABLE 21 (cont)

SUMMARY OF 2 DAY LOST LIST FORECAST METHODS

DATA SET	METHOD	MSE	MAPE
TEST	ARRES	509.134	23.393
TEST	HOLT'S	400.504	19.539
TEST	WINTER'S	406.390	19.535
TEST	NF1	452.696	21.903
* YEAR 88	MULT REGR	390.207	20.335
YEAR 88	NF1	641.370	27.263

* BEST RESULTS

The best method for forecasting is multiple regression with a MSE of 390.207. This method had a low MAPE of 20.335 over the entire 1988 data set.

Table 22 is a summary of all the forecasting methods results on the five day lost list.

TABLE 22

SUMMARY OF 5 DAY LOST LIST FORECAST METHODS

DATA SET	METHOD	MSE	MAPE
MODEL	EXPON	99.014	16.795
MODEL	ARRES	139.193	19.959
MODEL	HOLT'S	71.705	13.411
MODEL	WINTER'S	72.195	13.488
MODEL	NF1	68.412	12.996

TABLE 22 (cont)

SUMMARY OF 5 DAY LOST LIST FORECAST METHODS

DATA SET	METHOD	MSE	MAPE
TEST	EXPON	119.945	16.814
TEST	ARRES	254.019	21.151
TEST	HOLT'S	103.997	15.946
TEST	WINTER'S	105.168	16.122
TEST	NF1	97.848	15.210
* YEAR 88	MULT REGR	68.947	10.592
YEAR 88	NF1	92.350	12.808

* BEST RESULTS

The best method for forecasting is multiple regression with a MSE of 68.947. This method had a low MAPE of 10.592 over the entire 1988 data set. The NF1 method is a close second with a MSE of 97.848 and MAPE of 12.808.

VI. Conclusions and Recommendations

Conclusions

The results of this study reveal several interesting facts about what does and does not cause the lost lists to increase. Causation analysis, using simple linear regression, reveals that changes in the lost lists are partially due to changes in solar activity. However, due to the low correlation, it is likely that solar activity is one of several causes in determining the size of the lost lists. The results also show that geomagnetic field strength does not cause the lost lists to change. None of the regressions show geomagnetic field strength as a cause of variance in either the two or five day lost lists.

Another result of causation analysis is that a decrease in the number of observations arriving at the SSC does not cause the lost lists to increase. This is a surprising result. However, when the lost lists increase, some of the sensors send in more observations. Specifically, when the two day lost list increases, three sensors respond by increasing their number of daily observations. When the five day lost list increases, four sensors respond by sending in more observations. At a time when the SSC needs more observations, the most capable phased arrays in the network are not responding to increasing tasking requirements.

The final result of causation analysis worth noting is that there is a high percentage of satellites that begin on the two day lost list and, three days later, end up on the five day list. At least forty five percent of the satellites on the two day list will be on the five day lost list.

The prediction analysis yields good predictors for both lost lists as well as information on lost list data patterns. Explanatory forecasting produces a better predictor than any of the time series models.

In the case of the two day lost list the multiple regression model explains 41.83% of the variance with an MSE of 390.207. For the five day list, the same regression technique explains 89.65% with an MSE of 68.9474.

The time series analysis shows that the two day lost list has a strong stationary pattern while the five day list contains a trend. The best time-series predictor for the two day lost list is exponential smoothing. For the five day lost list the best predictor is Holt's two parameter smoothing. No seasonality is found in any of the four data sets in this time-series analysis.

Recommendations

In the progression of this thesis the author has discovered several areas that hold promise for future research. First, the time series approach could be expanded. Decomposition methods could be used to divide the data into subpatterns that identify each component of the time series separately. Such a breakdown would improve accuracy in forecasting and aid in better understanding the behavior of the series. Also, the inclusion of other time series techniques such as Box Jenkins, Univariate and Multivariate, may provide better results.

The second recommendation is to obtain a data set longer than two years with more independent variables. Inclusion of independent variables, such as total satellite population and number of current satellite breakups, would give an indication of how the lost list changes when the sensors are busy with other tasking requirements. The seven sensor variables could be subdivided into different correlation categories based on their ASTAT correlation with the satellite's element set. Using a longer data set may also allow identification of the seasonality of the eleven year solar cycle.

APPENDIX A: Data Set

Page

DATE	LOST2	LOST3	LOST4	LOST5	AP LOADS	AP CPU
01-Jan-88					23	2857
02-Jan-88	45	8	14	72	43	2429
03-Jan-88	104	22	7	60	46	2829
04-Jan-88	85	30	10	62	48	3070
05-Jan-88	60	27	13	59	32	9320
06-Jan-88	95	29	12	65	23	6753
07-Jan-88	83	24	18	64	37	2001
08-Jan-88	62	43	16	74	24	1318
09-Jan-88	104	32	24	79	32	1217
10-Jan-88	51	21	5	81	23	2752
11-Jan-88	59	9	10	69	35	2404
12-Jan-88	63	22	2	75	22	1547
13-Jan-88	69	30	17	71	28	715
14-Jan-88	67	23	19	74	56	2828
15-Jan-88	68	23	11	83	70	1831
16-Jan-88	87	20	10	86	39	1390
17-Jan-88	99	26	10	78	51	2561
18-Jan-88	154	28	15	78	77	3173
19-Jan-88	151	38	8	83	50	2720
20-Jan-88	98	98	17	81	67	5673
21-Jan-88	141	32	51	84	44	2118
22-Jan-88	60	52	20	122	49	3071
23-Jan-88	66	10	6	81	26	1575
24-Jan-88	62	23	6	78	67	2571
25-Jan-88	103	12	6	69	53	2586
26-Jan-88	71	29	7	67	47	8559
27-Jan-88	79	34	12	68	42	2380
28-Jan-88	87	16	19	65	46	1996
29-Jan-88	68	28	12	68	30	1291
30-Jan-88	104	25	10	69	36	2651
31-Jan-88	77	24	6	65	60	2273
01-Feb-88	92	25	17	66	31	1403
02-Feb-88	79	22	12	70	54	3514
03-Feb-88	59	21	10	71	40	842
04-Feb-88						
05-Feb-88	95	25	12	80	17	8536
06-Feb-88	65	19	13	82	37	9525
07-Feb-88	25	20	11	87	48	5499
08-Feb-88	53	9	9	88	52	6621
09-Feb-88	58	26	3	94	46	1649
10-Feb-88	72	37	14	94	58	6544
11-Feb-88	112	40	19	97	56	3255
12-Feb-88	79	28	13	99	48	2641
13-Feb-88	66	16	4	89	34	2609
14-Feb-88	59	10	5	80	58	2321
15-Feb-88	35	17	5	75	78	11676
16-Feb-88	40	7	4	75	21	1480
17-Feb-88	22	11	3	75	40	2107
18-Feb-88	41	7	8	64	41	1303

DATE	LOST2	LOST3	LOST4	LOST5	AP LOADS	AP CPU
19-Feb-88	57	15	6	61	34	983
20-Feb-88	40	18	7	64	35	2971
21-Feb-88	30	13	10	63	35	3178
22-Feb-88	36	10	4	55	39	1843
23-Feb-88	30	9	4	54	35	10333
24-Feb-88	57	12	7	45	25	950
25-Feb-88	76	23	8	46	28	2086
26-Feb-88	71	43	9	41	39	1378
27-Feb-88	125	49	37	44	37	3195
28-Feb-88	78	51	27	67	48	968
29-Feb-88	57	26	26	80	82	3328
01-Mar-88	62	17	10	64	80	2512
02-Mar-88	72	14	7	39	62	11831
03-Mar-88	78	25	4	38	25	7303
04-Mar-88	50	21	18	37	37	20900
05-Mar-88	52	20	11	43	62	8739
06-Mar-88	44	17	6	41	82	12185
07-Mar-88	43	9	7	32	77	3470
08-Mar-88	32	12	1	37	76	2388
09-Mar-88	44	7	5	33	45	2871
10-Mar-88	46	8	4	31	49	3052
11-Mar-88	47	27	7	31	34	1416
12-Mar-88	123	18	11	34	36	2428
13-Mar-88	76	38	13	38	23	10088
14-Mar-88	52	15	15	41	62	2081
15-Mar-88	44	7	5	37	61	5897
16-Mar-88	45	11	6	38	44	1880
17-Mar-88	65	5	5	36	28	1315
18-Mar-88	65	19	3	36	39	22459
19-Mar-88	52	18	10	32	64	1318
20-Mar-88	34	11	5	32	48	3754
21-Mar-88	51	5	6	31	47	1184
22-Mar-88	67	15	1	29	70	3234
23-Mar-88	83	21	8	28	47	2364
24-Mar-88	65	20	7	31	50	1534
25-Mar-88	55	27	11	35	63	2395
26-Mar-88	66	18	19	40	27	745
27-Mar-88	65	29	5	41	35	893
28-Mar-88	60	13	10	33	50	5001
29-Mar-88	69	11	7	35	43	4493
30-Mar-88	114	10	1	32	62	3105
31-Mar-88	100	52	9	24	31	883
01-Apr-88	83	66	37	31	37	1534
02-Apr-88	72	46	40	55	60	2023
03-Apr-88	56	28	33	85	68	2608
04-Apr-88	63	15	15	80	49	2130
05-Apr-88	45	11	9	35	29	1345
06-Apr-88	78	25	8	32	34	3424
07-Apr-88	101	32	10	33	65	4390

DATE	LOST2	LOST3	LOST4	LOST5	AP LOADS	AP CPU
08-Apr-88	66	33	11	34	50	8010
09-Apr-88	65	27	16	34	44	2577
10-Apr-88	56	12	9	36	61	2389
11-Apr-88	63	18	5	28	42	1786
12-Apr-88	76	25	10	26	59	1920
13-Apr-88	66	20	10	24	64	5838
14-Apr-88	77	16	11	29	33	2056
15-Apr-88	67	39	9	33	32	748
16-Apr-88	66	25	10	34	58	1929
17-Apr-88	41	22	11	36	59	1770
18-Apr-88	42	15	6	32	63	1102
19-Apr-88	50	12	8	26	56	1989
20-Apr-88	59	16	12	23	46	1679
21-Apr-88	52	12	5	24	55	929
22-Apr-88	69	17	8	27	54	2646
23-Apr-88	57	20	4	30	49	1639
24-Apr-88	33	15	7	28	50	1515
25-Apr-88	53	12	5	34	32	885
26-Apr-88	69	30	8	31	61	1952
27-Apr-88	64	29	18	34	80	3043
28-Apr-88	77	22	19	41	69	2500
29-Apr-88	91	15	11	42	65	3602
30-Apr-88	122	12	6	35	53	1856
01-May-88	81	13	5	31	31	1468
02-May-88	54	12	4	25	27	1908
03-May-88	65	15	6	26	29	2243
04-May-88	54	23	10	30	52	4093
05-May-88	72	12	13	31	59	2356
06-May-88	62	28	5	34	50	2661
07-May-88	88	19	10	34	45	1485
08-May-88	104	31	8	34	48	1279
09-May-88	99	24	10	33	36	864
10-May-88	65	41	12	36	43	1966
11-May-88	88	22	20	41	45	3104
12-May-88	129	43	16	48	59	4089
13-May-88	140	104	42	61	53	2534
14-May-88	96	68	24	69	66	2220
15-May-88	27	14	16	33	51	1579
16-May-88	56	10	8	30	45	13138
17-May-88	54	13	4	28	55	2042
18-May-88	61	16	6	24	50	612
19-May-88	68	15	10	27	55	1402
20-May-88	66	26	7	27	64	8286
21-May-88	59	24	13	30	45	1398
22-May-88	43	12	12	36	80	7374
23-May-88	61	23	9	38	57	2445
24-May-88	86	21	9	23	51	1839
25-May-88	62	12	7	23	62	2058
26-May-88	66	13	7	22	43	1246

DATE	LOST2	LOST3	LOST4	LOST5	AP LOADS	AP CPU
27-May-88	76	29	8	24	35	5350
28-May-88	44	22	16	24	24	1657
29-May-88	34	16	9	27	28	1191
30-May-88	46	10	8	21	30	1936
31-May-88	46	20	7	25	32	655
01-Jun-88	63	23	14	26	48	794
02-Jun-88	87	16	6	30	58	2053
03-Jun-88	80	35	4	27	24	842
04-Jun-88	79	43	21	27	29	2349
05-Jun-88	45	27	12	31	40	1268
06-Jun-88	40	13	12	32	66	3589
07-Jun-88	45	11	4	19	53	4124
08-Jun-88	70	23	6	19	46	1949
09-Jun-88	91	17	6	19	60	8179
10-Jun-88	59	23	5	21	39	9101
11-Jun-88	62	11	11	19	32	1692
12-Jun-88	37	21	5	23	35	1434
13-Jun-88	37	17	12	18	36	14065
14-Jun-88	45	20	8	26	56	6095
15-Jun-88	57	19	17	26	57	3023
16-Jun-88					8	2122
17-Jun-88					25	1134
18-Jun-88	102	45	35	37	43	7510
19-Jun-88	41	30	12	44	46	1255
20-Jun-88	38	15	10	38	48	6027
21-Jun-88	59	16	6	29	32	2348
22-Jun-88	66	13	5	28	58	3996
23-Jun-88	52	24	9	26	75	6213
24-Jun-88	44	20	16	27	45	2596
25-Jun-88	76	24	13	34	49	1641
26-Jun-88	56	34	12	30	46	1968
27-Jun-88	40	9	6	27	45	1871
28-Jun-88	65	17	8	24	12	611
29-Jun-88					19	3668
30-Jun-88	72	21	9	25	60	3726
01-Jul-88	50	21	13	23	42	1874
02-Jul-88	63	14	7	20	59	2357
03-Jul-88	48	12	5	18	36	1732
04-Jul-88	52	9	1	17	36	3780
05-Jul-88	77	10	4	15	37	1438
06-Jul-88	68	29	5	16	48	2854
07-Jul-88	89	28	19	21	53	2967
08-Jul-88	56	37	15	32	60	2853
09-Jul-88	39	17	14	35	45	1345
10-Jul-88					42	4013
11-Jul-88	45	12	5	34	39	1418
12-Jul-88	43	17	4	31	37	1271
13-Jul-88	47	12	7	28	39	1986
14-Jul-88	66	28	8	28	41	2819

DATE	LOST2	LOST3	LOST4	LOST5	AP LOADS	AP CPU
15-Jul-88	51	22	8	27	23	214
16-Jul-88	88	26	12	29	32	1958
17-Jul-88	44	23	13	16	28	427
18-Jul-88	40	23	9	33	27	492
19-Jul-88	39	12	14	39	34	887
20-Jul-88	58	20	9	42	17	410
21-Jul-88	54	41	14	45	35	714
22-Jul-88	39	18	10	50	43	1249
23-Jul-88	48	16	9	48	36	1046
24-Jul-88	47	10	10	43	47	1012
25-Jul-88	58	12	5	37	43	1947
26-Jul-88	65	25	5	38	29	2612
27-Jul-88	81	34	18	34	47	2033
28-Jul-88	59	35	23	37	37	937
29-Jul-88	58	31	30	50	24	842
30-Jul-88	66	30	23	66	32	1615
31-Jul-88	48	21	14	53	33	1028
01-Aug-88	31	20	14	41	81	3944
02-Aug-88	41	9	5	33	59	2036
03-Aug-88	42	15	5	29	42	1640
04-Aug-88	63	16	11	25	46	2129
05-Aug-88	50	27	7	27	35	740
06-Aug-88	47	14	8	18	50	1164
07-Aug-88	46	11	8	24	52	10789
08-Aug-88	50	9	9	25	64	4081
09-Aug-88	59	16	2	28	45	1594
10-Aug-88	56	21	8	27	24	1651
11-Aug-88	54	20	8	29	52	3865
12-Aug-88	71	21	9	29	22	538
13-Aug-88	125	25	11	31	38	1114
14-Aug-88	79	30	10	29	31	782
15-Aug-88	52	22	13	28	45	1688
16-Aug-88	71	16	6	32	48	1040
17-Aug-88	48	25	9	22	37	1079
18-Aug-88	38	23	16	26	24	1225
19-Aug-88	63	22	16	32	33	551
20-Aug-88	69	41	17	39	60	3000
21-Aug-88	58	26	19	43	34	1076
22-Aug-88	60	25	14	30	59	1734
23-Aug-88	55	19	4	23	57	1252
24-Aug-88	53	21	12	25	41	1155
25-Aug-88	62	18	9	25	42	3711
26-Aug-88	75	31	19	33	37	1363
27-Aug-88	88	37	21	44	53	1343
28-Aug-88	71	42	17	45	68	1516
29-Aug-88	71	31	20	49	45	1239
30-Aug-88	80	31	15	52	41	2532
31-Aug-88	71	38	19	44	35	1736
01-Sep-88	102	42	21	49	65	4056

DATE	LOST2	LOST3	LOST4	LOST5	AP LOADS	AP CPU
02-Sep-88	121	30	19	50	55	1131
03-Sep-88	91	40	16	46	45	801
04-Sep-88	52	50	18	31	37	774
05-Sep-88	82	23	23	32	45	728
06-Sep-88	80	21	13	40	46	1368
07-Sep-88	48	39	18	44	49	1672
08-Sep-88	70	14	14	46	50	2694
09-Sep-88	67	35	5	53	62	1549
10-Sep-88	59	35	25	50	30	701
11-Sep-88	62	29	15	62	29	484
12-Sep-88	64	22	16	69	21	243
13-Sep-88	69	31	10	72	26	544
14-Sep-88	86	27	18	72	56	1503
15-Sep-88	67	27	12	75	34	544
16-Sep-88	62	23	9	76	47	839
17-Sep-88	70	32	11	79	26	598
18-Sep-88	70	19	9	67	49	1336
19-Sep-88	62	14	8	53	41	2550
20-Sep-88	73	20	6	57	34	5251
21-Sep-88	87	27	10	50	37	584
22-Sep-88	132	46	30	59	53	765
23-Sep-88	167	72	35	76	32	2050
24-Sep-88	78	48	32	95	56	2287
25-Sep-88	75	25	25	80	42	1632
26-Sep-88	97	29	14	74	39	3808
27-Sep-88	110	26	13	50	53	2220
28-Sep-88	95	21	13	50	64	1735
29-Sep-88	132	17	11	54	57	870
30-Sep-88	99	89	14	60	54	1754
01-Oct-88	107	56	63	81	61	1984
02-Oct-88	84	40	39	108	64	1938
03-Oct-88	119	32	25	145	57	1734
04-Oct-88	93	41	13	122	38	1534
05-Oct-88	85	53	26	111	67	1997
06-Oct-88	76	28	26	90	53	3001
07-Oct-88	66	41	16	83	49	1855
08-Oct-88	93	40	31	76	27	2200
09-Oct-88	93	29	17	63	71	2991
10-Oct-88	102	15	8	58	80	2955
11-Oct-88	61	20	3	50	84	2598
12-Oct-88					16	2106
13-Oct-88					16	964
14-Oct-88					34	2274
15-Oct-88	98	80	87	95	7	846
16-Oct-88	60	49	66	117	73	2657
17-Oct-88	73	18	24	129	73	4078
18-Oct-88	100	28	14	122	60	2139
19-Oct-88	88	41	12	105	67	2439
20-Oct-88	120	24	15	84	84	3859

DATE	LOST2	LOST3	LOST4	LOST5	AP LOADS	AP CPU
21-Oct-88	143	47	11	92	64	2473
22-Oct-88	134	83	25	104	67	3694
23-Oct-88	113	56	50	94	89	4148
24-Oct-88	46	28	13	65	92	12843
25-Oct-88	75	24	17	66	47	1901
26-Oct-88	192	30	14	72	80	4101
27-Oct-88	87	63	14	81	82	7202
28-Oct-88	86	29	20	82	72	6992
29-Oct-88	68	37	12	80	90	4281
30-Oct-88	63	23	16	68	105	5178
31-Oct-88	51	23	11	52	67	3634
01-Nov-88	45	19	13	52	89	14333
02-Nov-88	78	22	14	57	65	2334
03-Nov-88	165	33	11	57	75	1314
04-Nov-88	142	64	16	59	69	1915
05-Nov-88	119	53	28	64	62	2262
06-Nov-88	111	48	26	80	38	1629
07-Nov-88	79	55	24	93	97	4395
08-Nov-88	93	50	23	89	49	3042
09-Nov-88	82	42	33	91	57	3804
10-Nov-88	69	19	21	94	68	2284
11-Nov-88	66	21	10	85	49	1449
12-Nov-88	74	17	11	84	66	3568
13-Nov-88	46	13	7	74	79	2668
14-Nov-88	60	12	3	57	84	2901
15-Nov-88	53	12	3	58	71	4615
16-Nov-88	66	24	8	58	67	3538
17-Nov-88	126	17	7	54	52	2335
18-Nov-88	81	52	7	53	54	2089
19-Nov-88	88	23	25	40	78	3228
20-Nov-88	53	18	11	45	83	3475
21-Nov-88	43	15	12	48	88	3502
22-Nov-88	92	19	6	46	63	3116
23-Nov-88	73	21	9	44	93	4044
24-Nov-88	87	24	12	43	81	2849
25-Nov-88	142	30	13	48	72	3111
26-Nov-88	83	27	12	48	85	4858
27-Nov-88	44	20	9	50	63	2172
28-Nov-88	54	17	8	51	58	2287
29-Nov-88	61	16	2	44	55	2141
30-Nov-88	52	11	4	38	82	4346
01-Dec-88	59	10	5	32	91	3378
02-Dec-88	63	9	5	28	52	2195
03-Dec-88	65	21	8	26	59	2552
04-Dec-88	65	31	10	32	62	1812
05-Dec-88	59	24	11	35	63	2475
06-Dec-88	68	15	8	32	63	1814
07-Dec-88	51	19	10	34	84	3695
08-Dec-88	62	19	8	41	35	1322

DATE	LOST2	LOST3	LOST4	LOST5	AP LOADS	AP CPU
09-Dec-88	52	31	11	52	44	933
10-Dec-88	55	21	16	53	56	3110
11-Dec-88	91	32	15	60	76	2512
12-Dec-88	85	39	21	72	30	2912
13-Dec-88	75	31	32	83	44	3109
14-Dec-88	119	44	27	107	46	2060
15-Dec-88	113	49	22	126	58	2974
16-Dec-88	98	76	40	140	72	2661
17-Dec-88	61	25	30	146	106	2938
18-Dec-88	93	17	7	96	77	3722
19-Dec-88	96	43	8	90	95	3935
20-Dec-88	112	61	25	77	41	2561
21-Dec-88	93	37	20	76	65	2979
22-Dec-88	112	53	22	72	55	1646
23-Dec-88	125	49	33	85	93	5667
24-Dec-88	60	61	27	98	61	4872
25-Dec-88	87	19	24	97	55	2612
26-Dec-88	56	24	5	74	51	1712
27-Dec-88	53	26	14	62	63	2268
28-Dec-88	72	14	13	60	81	2282
29-Dec-88	66	29	8	68	61	2251
30-Dec-88	65	23	15	74	45	1741
31-Dec-88	69	20	12	78	39	1244

DATE	F10 BAR	F10 ACT	AP MAX	AP AVG	EGL	PAR
01-Jan-88	99	104	13	7	7152	6386
02-Jan-88	99	97	89	45		9790
03-Jan-88	99	105	19	12	6690	10089
04-Jan-88	99	102	67	18	9814	8483
05-Jan-88	99	103	28	20	6767	8929
06-Jan-88	99	105	112	37	12421	7464
07-Jan-88	99	106	76	26	12085	9943
08-Jan-88	99	109	39	24	9641	9928
09-Jan-88	100	111	14	9	10204	10467
10-Jan-88	100	104	9	7	4156	4942
11-Jan-88	100	108	36	15	11290	6852
12-Jan-88	100	114	58	23	9696	8100
13-Jan-88	100	117	22	10	10132	8477
14-Jan-88	100	118	171	57	7571	7782
15-Jan-88	100	122	181	86	13087	8966
16-Jan-88	100	127	17	10	9999	9450
17-Jan-88	100	120	16	10	10279	10080
18-Jan-88	100	115	34	14	11392	8209
19-Jan-88	101	118	37	16	6831	7275
20-Jan-88	101	116	16	12	788	8591
21-Jan-88	101	115	18	11	13473	9024
22-Jan-88	102	108	18	10	10511	8688
23-Jan-88	102	108	9	7	11611	8674
24-Jan-88	102	106	11	8	10661	8201
25-Jan-88	102	98	14	10	12251	8332
26-Jan-88	102	97	24	13	9412	8066
27-Jan-88	102	105	33	19	10760	7634
28-Jan-88	102	106	18	11	11003	7890
29-Jan-88	102	102	10	7	8489	6247
30-Jan-88	102	103	9	7	8211	8215
31-Jan-88	102	106	9	7	7377	9054
01-Feb-88	102	109	10	7	9061	10494
02-Feb-88	102	107	15	9	6528	12193
03-Feb-88	102	107	13	7	10488	11887
04-Feb-88	102	106	20	9	346	959
05-Feb-88	102	106	92	45	7051	4637
06-Feb-88	102	107	18	12	10438	11509
07-Feb-88	102	108	11	8	8564	11235
08-Feb-88	103	105	10	8	9260	10092
09-Feb-88	104	104	25	15	7664	9191
10-Feb-88	103	103	32	18	7852	7828
11-Feb-88	103	102	25	14	7828	9676
12-Feb-88	103	104	46	22	8691	8227
13-Feb-88	103	106	34	19	10598	8947
14-Feb-88	103	105	17	10	8320	10598
15-Feb-88	103	103	56	26	10140	10525
16-Feb-88	103	104	40	21	9620	9760
17-Feb-88	103	109	31	18	7550	8833
18-Feb-88	103	115	49	22	8018	8783

DATE	F10 BAR	F10 ACT	AP MAX	AP AVG	EGL	PAR
19-Feb-88	103	112	13	9	9241	8463
20-Feb-88	103	109	12	8	10484	9435
21-Feb-88	103	107	61	35	10543	9483
22-Feb-88	103	105	155	123	11076	8474
23-Feb-88	103	102	100	48	8838	9032
24-Feb-88	103	102	30	17	11030	9435
25-Feb-88	103	98	20	16	9016	8630
26-Feb-88	103	99	22	15	8461	9172
27-Feb-88	103	98	20	11	9869	11012
28-Feb-88	103	99	14	9	9053	11060
29-Feb-88	103	105	11	7	7477	9212
01-Mar-88	103	103	14	9	6391	9336
02-Mar-88	103	101	17	11	9683	9109
03-Mar-88	104	103	17	13	7830	8589
04-Mar-88	104	110	65	34	9248	8750
05-Mar-88	104	110	13	11	9311	9473
06-Mar-88	104	109	60	31	8526	9472
07-Mar-88	104	109	32	19	9616	8651
08-Mar-88	105	107	73	36	8099	8564
09-Mar-88	105	103	33	19	9437	8461
10-Mar-88	105	101	31	17	6160	9054
11-Mar-88	105	104	37	19	121	8538
12-Mar-88	105	105	16	12	4554	9621
13-Mar-88	105	109	11	8	4470	9173
14-Mar-88	105	112	26	18	9725	8361
15-Mar-88	105	119	40	25	7876	8396
16-Mar-88	106	121	45	23	7656	7943
17-Mar-88	106	[illegible]	23	14	5576	6642
18-Mar-88	106	117	17	12	7858	5632
19-Mar-88	108	118	14	11	9587	9358
20-Mar-88	107	115	22	11	7803	8887
21-Mar-88	107	119	13	9	9077	9015
22-Mar-88	108	118	14	10	4943	7650
23-Mar-88	108	122	18	11	8561	8259
24-Mar-88	108	122	14	10	5847	8270
25-Mar-88	108	129	30	17	8520	7669
26-Mar-88	108	129	146	61	8978	8824
27-Mar-88	109	131	102	48	8028	8768
28-Mar-88	109	130	82	46	8808	8955
29-Mar-88	109	132	105	56	7053	8702
30-Mar-88	110	129	127	48	7849	9288
31-Mar-88	110	134	36	21	8772	9824
01-Apr-88	110	127	37	26	8321	9117
02-Apr-88	111	127	62	33	9320	10276
03-Apr-88	111	128	187	67	9169	9825
04-Apr-88	111	123	198	103	8710	7861
05-Apr-88	111	114	95	41	7975	7749
06-Apr-88	111	117	135	70	9193	9338
07-Apr-88	112	120	40	22	8233	8329

DATE	F10 BAR	F10 ACT	AP MAX	AP AVG	EGL	PAR
08-Apr-88	112	125	30	17	9426	9169
09-Apr-88	112	127	36	18	9163	9370
10-Apr-88	112	127	44	21	6683	8764
11-Apr-88	112	131	24	15	8633	8512
12-Apr-88	113	136	36	21	7330	7751
13-Apr-88	113	134	27	17	7661	7580
14-Apr-88	113	145	24	17	4953	7338
15-Apr-88	113	143	23	14	7414	8271
16-Apr-88	113	147	35	18	9057	8709
17-Apr-88	114	144	22	12	8365	8119
18-Apr-88	114	144	18	15	8113	7278
19-Apr-88	114	137	19	15	7241	7320
20-Apr-88	115	134	20	13	8624	7133
21-Apr-88	115	126	28	15	5017	7580
22-Apr-88	115	119	177	78	6280	7714
23-Apr-88	115	110	91	33	9032	8748
24-Apr-88	115	104	15	12	8276	8429
25-Apr-88	115	105	18	14	8630	8160
26-Apr-88	115	105	26	15	7884	9154
27-Apr-88	115	103	23	15	8205	7963
28-Apr-88	115	101	38	23	8454	9011
29-Apr-88	115	100	20	14	704	8040
30-Apr-88	115	101	20	15	9543	7975
01-May-88	115	103	18	12	5989	8653
02-May-88	115	107	22	14	8666	8249
03-May-88	115	121	22	15	6064	7852
04-May-88	115	125	46	26	7430	7206
05-May-88	115	119	85	32	8666	7433
06-May-88	116	114	317	125	6775	7581
07-May-88	116	111	30	21	8330	9375
08-May-88	116	115	42	24	8563	9693
09-May-88	116	120	37	20	6997	9241
10-May-88	116	114	27	20	5970	8752
11-May-88	116	112	20	14	7159	6070
12-May-88	116	109	17	13	6050	
13-May-88	116	104	18	12	9461	7158
14-May-88	116	103	17	11	8798	9935
15-May-88	116	101	25	13	8378	9752
16-May-88	116	101	38	22	9271	8824
17-May-88	116	101	71	41	8503	7778
18-May-88	116	104	77	38	7459	8127
19-May-88	116	102	29	18	6777	8626
20-May-88	116	104	19	15	8503	9385
21-May-88	116	110	33	22	8897	9108
22-May-88	116	111	26	18	3575	9543
23-May-88	116	119	30	16	5067	8983
24-May-88	116	117	34	17	7607	8154
25-May-88	116	119	24	15	6107	8891
26-May-88	117	125	42	16	4590	9903

DATE	F10 BAR	F10 ACT	AP MAX	AP AVG	EGL	PAR
27-May-88	117	127	15	10	7870	8779
28-May-88	117	127	20	12	9652	8935
29-May-88	118	136	26	16	8569	9003
30-May-88	118	139	29	21	9017	9116
31-May-88	119	145	25	16	7144	9082
01-Jun-88	119	150	20	14	8480	7311
02-Jun-88	119	144	20	13	8620	9654
03-Jun-88	120	145	18	11	8806	8447
04-Jun-88	120	147	21	13	9231	9910
05-Jun-88	121	147	33	19	9171	9345
06-Jun-88	121	154	49	19	8782	8493
07-Jun-88	122	160	24	14	7569	7892
08-Jun-88	122	163	24	15	8498	8036
09-Jun-88	123	165	28	15	10590	9094
10-Jun-88	124	145	24	16	6337	8743
11-Jun-88	124	134	21	16	8081	9041
12-Jun-88	124	122	13	10	8336	8904
13-Jun-88	124	112	20	13	10500	7036
14-Jun-88	124	108	47	37	8287	7934
15-Jun-88	124	111	25	18	9245	8421
16-Jun-88	124	118	20	14	1429	3375
17-Jun-88	124	121	34	21	5732	4837
18-Jun-88	124	122	34	21	9280	9441
19-Jun-88	124	116	67	33	6788	8530
20-Jun-88	124	115	73	35	7833	8959
21-Jun-88	124	121	38	16	9273	7567
22-Jun-88	124	119	33	22	7578	9757
23-Jun-88	124	125	22	17	8073	8647
24-Jun-88	124	135	46	31	8385	8648
25-Jun-88	124	150	83	48	8892	9759
26-Jun-88	124	155	59	29	7139	9355
27-Jun-88	124	155	48	21	9361	8249
28-Jun-88	125	178	49	22	4636	8007
29-Jun-88	126	183	75	45	7297	3396
30-Jun-88	126	184	94	49	6513	8982
01-Jul-88	127	193	56	31	9576	9090
02-Jul-88	128	192	56	26	8906	9100
03-Jul-88	128	187	27	18	5580	9155
04-Jul-88	129	175	22	15	8443	8929
05-Jul-88	130	166	25	14	7351	7444
06-Jul-88	130	152	31	23	6643	8163
07-Jul-88	130	147	31	20	7478	8755
08-Jul-88	130	138	37	22	9250	8100
09-Jul-88	130	133	16	12	9489	9216
10-Jul-88	130	134	29	16	5403	5135
11-Jul-88	130	137	53	36	10497	8236
12-Jul-88	130	133	40	30	7876	8699
13-Jul-88	130	138	19	14	10537	8552
14-Jul-88	130	145	25	18	6738	9028

DATE	F10 BAR	F10 ACT	AP MAX	AP AVG	EGL	PAR
15-Jul-88	130	146	32	22	9410	8313
16-Jul-88	130	149	83	42	8557	8542
17-Jul-88	131	157	29	17	8643	8476
18-Jul-88	131	148	53	24	9069	8438
19-Jul-88	131	138	43	20	8223	8221
20-Jul-88	131	137	18	13	9163	8576
21-Jul-88	131	141	245	65	6983	8826
22-Jul-88	131	137	91	48	8194	8342
23-Jul-88	132	140	72	32	8560	9069
24-Jul-88	132	134	23	16	8474	9109
25-Jul-88	132	137	24	14	10178	8754
26-Jul-88	133	145	61	38	10625	8282
27-Jul-88	134	157	47	27	9625	8726
28-Jul-88	134	170	31	20	8028	8985
29-Jul-88	135	180	27	17	10453	8528
30-Jul-88	136	183	27	18	9664	9344
31-Jul-88	137	187	26	19	8420	9007
01-Aug-88	137	176	41	21	9822	9467
02-Aug-88	138	182	25	17	7543	9221
03-Aug-88	139	173	33	18	6074	7925
04-Aug-88	139	159	23	11	9038	7671
05-Aug-88	140	155	27	20	9848	8553
06-Aug-88	140	160	20	14	9241	8443
07-Aug-88	141	166	20	13	8487	8070
08-Aug-88	141	181	19	13	9232	7804
09-Aug-88	142	180	116	40	7401	9834
10-Aug-88	143	180	29	17	8993	6652
11-Aug-88	144	173	24	16	5750	6990
12-Aug-88	144	158	33	24	1666	7643
13-Aug-88	145	157	44	30	9868	8167
14-Aug-88	146	149	51	34	6793	7844
15-Aug-88	146	140	65	30	7381	8222
16-Aug-88	146	135	31	17	8593	7529
17-Aug-88	147	138	16	12	10052	8180
18-Aug-88	147	125	48	20	7801	8206
19-Aug-88	147	121	25	15	9638	8737
20-Aug-88	147	115	48	27	8873	8891
21-Aug-88	147	113	30	13	8940	8689
22-Aug-88	147	113	105	38	10119	8497
23-Aug-88	147	120	34	21	9603	9048
24-Aug-88	147	131	20	15	8725	8228
25-Aug-88	147	140	33	24	7006	7469
26-Aug-88	147	153	32	17	9286	7843
27-Aug-88	148	163	45	29	9520	8436
28-Aug-88	148	171	35	18	8505	8553
29-Aug-88	149	185	44	29	10317	8150
30-Aug-88	149	187	66	31	10062	7978
31-Aug-88	150	190	39	26	8854	8580
01-Sep-88	150	189	91	39	8764	8636

DATE	F10 BAR	F10 ACT	AP MAX	AP AVG	EGL	PAR
02-Sep-88	150	176	53	26	10123	8012
03-Sep-88	151	174	42	19	10065	8955
04-Sep-88	151	163	23	15	7808	7317
05-Sep-88	151	163	13	10	9697	6954
06-Sep-88	151	150	14	10	10552	8006
07-Sep-88	150	143	16	11	9963	8386
08-Sep-88	150	136	18	12	10216	8651
09-Sep-88	150	126	16	11	10705	8274
10-Sep-88	150	114	38	17	11094	8562
11-Sep-88	150	120	121	65	11180	8367
12-Sep-88	150	124	100	36	7775	6933
13-Sep-88	150	122	49	24	11054	12322
14-Sep-88	151	129	34	19	10948	9913
15-Sep-88	151	125	27	19	9120	12657
16-Sep-88	151	127	27	13	10512	12086
17-Sep-88	151	133	50	34	10355	12313
18-Sep-88	151	139	99	51	7983	12204
19-Sep-88	151	138	75	43	9381	11280
20-Sep-88	152	149	24	18	8072	12142
21-Sep-88	152	156	24	15	5369	12479
22-Sep-88	153	178	49	29	492	8525
23-Sep-88	153	180	31	19	17010	8579
24-Sep-88	153	179	18	13	9086	8386
25-Sep-88	153	177	53	19	8090	8528
26-Sep-88	153	173	17	11	9304	8141
27-Sep-88	153	173	15	11	7488	8476
28-Sep-88	153	171	16	11	8720	8342
29-Sep-88	153	173	13	10	7824	7836
30-Sep-88	153	172	18	13	10104	8307
01-Oct-88	152	179	25	17	5556	9336
02-Oct-88	153	195	12	9	7654	8551
03-Oct-88	153	202	15	10	9913	9297
04-Oct-88	154	189	39	15	7881	8728
05-Oct-88	154	189	41	24	9861	8387
06-Oct-88	155	188	75	40	8058	9086
07-Oct-88	155	181	22	13	12635	8868
08-Oct-88	156	174	23	13	10928	8907
09-Oct-88	156	176	33	22	10423	9417
10-Oct-88	156	179	193	103	10902	8896
11-Oct-88	157	170	72	27	7510	6929
12-Oct-88	157	149	25	16	4727	5586
13-Oct-88	157	159	20	15	1670	1536
14-Oct-88	157	151	17	11	8003	4700
15-Oct-88	157	150	26	11	3294	4258
16-Oct-88	157	155	19	14	7854	9905
17-Oct-88	157	178	42	19	11469	9187
18-Oct-88	157	178	49	34	9961	8430
19-Oct-88	158	166	29	20	12287	8821
20-Oct-88	158	168	37	23	6184	8395

DATE	F10 BAR	F10 ACT	AP MAX	AP AVG	EGL	PAR
21-Oct-88	159	166	16	11	7214	8818
22-Oct-88	159	166	16	9	11245	9214
23-Oct-88	159	171	17	10	9845	9870
24-Oct-88	160	170	13	10	11593	10132
25-Oct-88	160	164	14	8	11450	9165
26-Oct-88	160	157	17	11	8274	7043
27-Oct-88	159	163	19	12	10123	7621
28-Oct-88	159	158	18	13	11979	7530
29-Oct-88	159	156	19	9	11675	8217
30-Oct-88	159	167	20	9	11004	8333
31-Oct-88	158	161	29	15	11692	8203
01-Nov-88	158	157	15	11	6483	1386
02-Nov-88	158	167	38	24	5936	7413
03-Nov-88	159	167	37	25	8149	8902
04-Nov-88	159	162	15	9	11299	7791
05-Nov-88	159	169	20	12	10326	9341
06-Nov-88	158	165	25	14	10687	9266
07-Nov-88	158	155	24	17	11392	8328
08-Nov-88	158	146	32	19	10696	7300
09-Nov-88	158	156	23	13	14206	9913
10-Nov-88	157	152	31	16	9963	7991
11-Nov-88	157	157	16	9	12686	7565
12-Nov-88	158	156	32	15	12904	8173
13-Nov-88	158	171	13	9	13081	8044
14-Nov-88	158	179	19	11	13096	7525
15-Nov-88	159	174	14	10	9110	7522
16-Nov-88	160	189	29	18	3538	7421
17-Nov-88	160	180	20	13	7806	7557
18-Nov-88	161	166	11	8	5999	7524
19-Nov-88	161	156	5	4	11008	7817
20-Nov-88	162	147	7	3	8800	7929
21-Nov-88	162	157	7	6	11533	7964
22-Nov-88	162	150	9	6	10871	8356
23-Nov-88	162	139	7	5	7454	7315
24-Nov-88	162	142	7	5	1010	8218
25-Nov-88	162	143	13	7	11114	8019
26-Nov-88	162	142	27	18	10820	7882
27-Nov-88	161	145	21	11	10104	7571
28-Nov-88	161	142	26	10	9487	7340
29-Nov-88	160	143	13	9	9573	7164
30-Nov-88	160	140	63	29	11444	7219
01-Dec-88	159	155	25	10	11137	7093
02-Dec-88	159	154	40	17	14137	7768
03-Dec-88	159	151	34	18	12854	7916
04-Dec-88	159	146	14	11	12979	7795
05-Dec-88	159	163	9	6	11589	7689
06-Dec-88	159	157	9	6	11777	7239
07-Dec-88	159	165	9	6	2970	7063
08-Dec-88	160	169	11	6	1242	6706

DATE	F10 BAR	F10 ACT	AP MAX	AP AVG	EGL	PAR
09-Dec-88	161	170	10	6	12167	7411
10-Dec-88	161	164	20	11	9236	6719
11-Dec-88	162	184	33	15	9631	7636
12-Dec-88	162	180	35	12	11554	7132
13-Dec-88	163	186	35	20	11236	8431
14-Dec-88	164	215	38	13	12111	8954
15-Dec-88	165	219	20	10	11564	8738
16-Dec-88	166	239	37	21	12625	9490
17-Dec-88	167	250	65	33	12537	9089
18-Dec-88	169	253	48	23	13419	8816
19-Dec-88	170	249	34	20	13200	8424
20-Dec-88	171	252	9	7	11023	9003
21-Dec-88	172	252	21	12	9722	6369
22-Dec-88	173	255	14	11	13672	7883
23-Dec-88	173	245	9	7	13128	8673
24-Dec-88	174	229	10	6	14020	8194
25-Dec-88	174	220	38	20	13168	7731
26-Dec-88	175	201	37	23	14335	7767
27-Dec-88	175	212	31	20	12393	7783
28-Dec-88	176	209	26	15	11304	7268
29-Dec-88	176	202	30	19	14450	7484
30-Dec-88	176	180	27	12	14385	6707
31-Dec-88	176	182	19	12	12991	7399

DATE	NAV	OTS	BLE	RBN	ELD
01-Jan-88	1773	1019	1408	885	1458
02-Jan-88	2614	1551	2259	1147	2524
03-Jan-88	2559	1669	2509	1182	2688
04-Jan-88	3119	1297	1804	1089	2339
05-Jan-88	2555	1547	1733	1132	2579
06-Jan-88	2489	2174	2451	890	2541
07-Jan-88	2534	1202	1890	1761	2748
08-Jan-88	2344	1803	1721	1560	2196
09-Jan-88	2516	1439	1984	1551	1479
10-Jan-88	1795	803	1070	628	1074
11-Jan-88	1833	1563	2085	1554	2400
12-Jan-88	2853	1666	1268	1188	2331
13-Jan-88	2453	1585	1571	1370	2543
14-Jan-88	2540	1849	1624	1244	2352
15-Jan-88	2464	1868	1948	1619	2552
16-Jan-88	2557	2336	2212	1659	2641
17-Jan-88	2527	1523	2557	3130	2700
18-Jan-88	2534	1878	2353	1579	2313
19-Jan-88	2625	1673	1802	1186	1471
20-Jan-88	2660	1745	1853	1256	2499
21-Jan-88	2705	2096	1870	1320	2430
22-Jan-88	2758	1510	2027	1434	1739
23-Jan-88	2275	1937	2178	1241	2372
24-Jan-88	2540	1939	2033	1280	2434
25-Jan-88	1826	1442	1663	1278	1708
26-Jan-88	3245	1640	1865	1233	1606
27-Jan-88	2879	1722	2180	771	1410
28-Jan-88	2399	1442	2151	1354	1216
29-Jan-88	2445	1755	2011	1330	1679
30-Jan-88	2420	1938	2234	1399	2512
31-Jan-88	2742	1998	2532	1521	2056
01-Feb-88	2895	2057	2406	1548	1775
02-Feb-88	3437	2446	2317	1537	1149
03-Feb-88	2407	2131	2067	1245	1311
04-Feb-88	697	86	149	42	36
05-Feb-88	809	1323	896	885	1105
06-Feb-88	2966	1896	2075	1636	1636
07-Feb-88	2697	1877	2468	1614	1673
08-Feb-88	2731	2082	1822	1489	1450
09-Feb-88	2707	2171	1821	1645	1837
10-Feb-88	2745	1732	1841	1436	1369
11-Feb-88	2936	2186	1149	1578	1305
12-Feb-88	2389	2207	1856	1202	1566
13-Feb-88	2384	2164	2292	1512	1593
14-Feb-88	2818	1588	2580	1474	1600
15-Feb-88	2412	1887	2231	1454	1612
16-Feb-88	2697	2648	1878	1387	1441
17-Feb-88	2587	1817	2282	1410	1558
18-Feb-88	2463	1911	1850	1390	1960

DATE	NAV	OTS	BLE	RBN	ELD
19-Feb-88	2474	2134	2172	1611	1770
20-Feb-88	2579	1979	2319	1593	1914
21-Feb-88	2506	2270	2427	1182	1627
22-Feb-88	2498	2260	2162	1498	1746
23-Feb-88	2411	1861	2299	1499	1766
24-Feb-88	2346	1667	2372	1067	2010
25-Feb-88	2439	1682	2747	1609	1276
26-Feb-88	2488	2042	1885	1663	1911
27-Feb-88	2587	1422	2115	1875	1871
28-Feb-88	2750	1615	2343	1455	1621
29-Feb-88	2752	1643	1093	1616	1838
01-Mar-88	2624	2233	[illegible]398	1697	1787
02-Mar-88	2743	1752	2865	1499	1944
03-Mar-88	2356	1636	2189	1414	1324
04-Mar-88	2374	1708	2912	1523	2034
05-Mar-88	2510	1754	1876	1517	1602
06-Mar-88	2454	1577	1595	1643	1716
07-Mar-88	2435	1763	1850	1449	1573
08-Mar-88	2493	1175	1597	1486	1195
09-Mar-88	2336	1632	1988	1001	1509
10-Mar-88	2383	1971	2033	1458	1844
11-Mar-88	2405	2583	2831	2487	2755
12-Mar-88	2707	2009	3044	3125	3532
13-Mar-88	2492	1784	1916	4728	2764
14-Mar-88	2556	1863	1561	2767	2656
15-Mar-88	2403	1724	1333	2573	2770
16-Mar-88	2523	1865	1675	2056	2583
17-Mar-88	1515	1498	1529	1538	1562
18-Mar-88	1569	1719	1276	1986	2190
19-Mar-88	2415	2233	2709	2746	2923
20-Mar-88	2355	2125	2342	2651	3186
21-Mar-88	2263	1615	1835	2407	2590
22-Mar-88	1781	1930	2302	2951	2425
23-Mar-88	2235	2171	2711	1959	2775
24-Mar-88	2482	1651	2823	1550	2258
25-Mar-88	2316	1746	2500	1563	1716
26-Mar-88	2251	2037	1734	1672	1857
27-Mar-88	2393	1812	2385	1540	1753
28-Mar-88	2480	1464	3019	3772	1901
29-Mar-88	2390	2395	2679	1000	2074
30-Mar-88	2469	2134	2451	1685	1926
31-Mar-88	2429	2562	2481	1914	1812
01-Apr-88	2892	2381	2571	1845	1969
02-Apr-88	2544	1830	2295	1637	1774
03-Apr-88	2460	2522	2482	1742	1778
04-Apr-88	2465	1439	1832	1700	2748
05-Apr-88	3207	1233	1112	1966	1888
06-Apr-88	2322	2226	2356	1451	1779
07-Apr-88	2386	3021	2334	1606	1615

DATE	NAV	OTS	BLE	RBN	ELD
08-Apr-88	2477	1944	2125	1470	1511
09-Apr-88	2442	2150	2132	1279	1595
10-Apr-88	2421	2751	2388	3084	1491
11-Apr-88	2368	1822	2015	1201	1464
12-Apr-88	2342	1685	2032	1170	1058
13-Apr-88	2382	1944	1658	1067	1358
14-Apr-88	2299	1859	1695	1256	1002
15-Apr-88	2301	1819	1715	1321	1447
16-Apr-88	2545	1526	2121	1191	1373
17-Apr-88	2271	1575	1990	1367	1277
18-Apr-88	2261	1628	2238	1256	1350
19-Apr-88	2209	1324	2472	1230	1101
20-Apr-88	2234	1632	1516	951	1316
21-Apr-88	2254	2061	2077	1377	1558
22-Apr-88	2187	1510	3120	1154	1378
23-Apr-88	2359	1460	2901	1199	1272
24-Apr-88	2365	1594	3434	1029	1277
25-Apr-88	2168	1817	3680	1157	1259
26-Apr-88	2348	1783	3373	1081	1428
27-Apr-88	2311	1815	3415	1320	901
28-Apr-88	2919	1585	3729	1715	1834
29-Apr-88	2731	2114	3196	1810	1958
30-Apr-88	2474	2416	3447	1451	1537
01-May-88	2330	1440	2154	1240	1484
02-May-88	2284	1900	2941	1267	1171
03-May-88	2257	1280	2404	1373	1541
04-May-88	2241	1555	1846	1138	1025
05-May-88	2243	1489	2833	1251	1499
06-May-88	2384	1810	3371	1313	1681
07-May-88	2224	1882	2901	1259	1483
08-May-88	2436	1760	2683	1033	1548
09-May-88	2322	1315	2362	974	1320
10-May-88	2316	2140	2778	1203	1199
11-May-88	2434	1760	2985	736	1388
12-May-88	2273	1597	3169	1266	1486
13-May-88	2414	1627	3295	1552	1523
14-May-88	2124	1342	2765	1414	1495
15-May-88	2591	1753	2642	1118	1374
16-May-88	2195	1548	2345	1203	1438
17-May-88	2191	1421	2340	1327	1458
18-May-88	2153	1499	2729	973	983
19-May-88	2616	1455	2816	1281	1391
20-May-88	2200	1768	1693	1246	1460
21-May-88	2199	1257	1504	1354	1326
22-May-88	2270	2245	1778	1212	1383
23-May-88	2181	1953	1667	1258	1362
24-May-88	2210	1529	1313	987	1232
25-May-88	2335	1824	1616	1361	1437
26-May-88	2151	1937	1726	1267	925

DATE	NAV	OTS	BLE	RBN	ELD
27-May-88	2247	1534	1715	1422	1288
28-May-88	2161	1595	1684	1443	1200
29-May-88	2117	1525	1267	1378	1320
30-May-88	2205	2007	1596	1262	1251
31-May-88	2101	1862	1738	1391	1332
01-Jun-88	2070	1705	1806	1229	977
02-Jun-88	2230	1872	1392	1265	1200
03-Jun-88	2219	1596	989	1036	1178
04-Jun-88	2184	1454	1159	1177	1306
05-Jun-88	2576	1724	1632	1121	1350
06-Jun-88	2080	1603	1266	1285	1381
07-Jun-88	2177	1943	1322	1310	1052
08-Jun-88	2536	1619	1228	982	1483
09-Jun-88	2450	1476	1469	1213	1421
10-Jun-88	2133	1316	1436	1227	1393
11-Jun-88	2301	1254	1498	1254	1248
12-Jun-88	2103	1084	1651	1282	1431
13-Jun-88	2219	1251	1728	1208	1423
14-Jun-88	2208	1499	1831	1300	1431
15-Jun-88	2151	1505	1814	1653	1609
16-Jun-88	767	369	427	314	370
17-Jun-88	706	861	417	1486	845
18-Jun-88	2400	1884	1950	2760	1479
19-Jun-88	2305	1240	1404	1978	1317
20-Jun-88	2273	1436	1953	2570	1570
21-Jun-88	2223	1535	1848	2364	1372
22-Jun-88	2281	1433	1971	1968	1095
23-Jun-88	2200	1693	1935	2464	1225
24-Jun-88	2201	1580	1751	1995	1545
25-Jun-88	2185	1611	1797	1941	1568
26-Jun-88	2268	1497	1446	2652	1531
27-Jun-88	2216	1517	1172	2098	1439
28-Jun-88	2137	1137	1564	1893	896
29-Jun-88	717	783	1034	1336	352
30-Jun-88	2121	1269	1690	2186	1390
01-Jul-88	2183	1494	1720	2348	1410
02-Jul-88	2310	1381	1652	2293	1156
03-Jul-88	2204	1473	1677	2285	1607
04-Jul-88	2133	1468	1609	2596	1520
05-Jul-88	1538	1502	1310	2419	1368
06-Jul-88	2248	1647	1896	1623	1554
07-Jul-88	2130	1675	1554	2237	1441
08-Jul-88	2140	1292	1663	1870	1347
09-Jul-88	2213	1054	1394	1942	1242
10-Jul-88	1499	618	795	1306	513
11-Jul-88	2255	920	1139	2168	1118
12-Jul-88	2135	1253	724	1863	2365
13-Jul-88	2166	1285	1369	2035	2241
14-Jul-88	2238	1416	1805	999	1815

DATE	NAV	OTS	BLE	RBN	ELD
15-Jul-88	1914	1395	1676	1937	1315
16-Jul-88	2216	984	1602	1551	1318
17-Jul-88	2280	1455	1438	2082	1273
18-Jul-88	2140	1514	1668	2029	1254
19-Jul-88	2138	1494	1767	2069	1393
20-Jul-88	2086	1562	1794	2162	1375
21-Jul-88	2070	1422	1533	2510	1017
22-Jul-88	2147	1254	1466	1937	1289
23-Jul-88	2307	1321	1452	1216	1386
24-Jul-88	2380	1395	1568	1174	1400
25-Jul-88	2292	1177	1323	1232	1308
26-Jul-88	2253	1331	1358	1257	1251
27-Jul-88	2377	1465	1751	1271	1362
28-Jul-88	1691	856	1514	1063	1394
29-Jul-88	2209	1396	1544	1026	1199
30-Jul-88	2321	1331	1286	985	1242
31-Jul-88	2344	1245	1223	1075	1122
01-Aug-88	2360	1047	976	1088	1266
02-Aug-88	2209	1250	1298	1009	1176
03-Aug-88	2259	1414	1670	1085	1328
04-Aug-88	2290	1375	1230	1046	1524
05-Aug-88	2166	1400	1524	1061	1193
06-Aug-88	2242	1344	1461	1077	1180
07-Aug-88	2417	1407	1490	1115	1258
08-Aug-88	2246	1320	1690	1095	1381
09-Aug-88	2199	1450	1597	1222	1291
10-Aug-88	2338	1517	1602	1221	1343
11-Aug-88	2498	1437	1659	1013	1176
12-Aug-88	2471	1456	831	1059	1267
13-Aug-88	2322	1027	1299	1162	1361
14-Aug-88	2607	1390	1368	1136	1302
15-Aug-88	2500	1426	1310	1184	1338
16-Aug-88	2392	1530	1501	1180	906
17-Aug-88	2381	1430	1783	1202	1801
18-Aug-88	2372	1425	1710	1329	1570
19-Aug-88	2341	1684	1417	1738	1612
20-Aug-88	2237	1622	1467	1252	1535
21-Aug-88	2310	1518	1696	1132	1467
22-Aug-88	2282	1498	1305	1148	1312
23-Aug-88	2319	1438	1737	1286	1129
24-Aug-88	2143	1415	1565	1206	1121
25-Aug-88	2158	1541	1250	909	1690
26-Aug-88	2200	1334	1655	1306	2710
27-Aug-88	1971	1326	1210	1376	1518
28-Aug-88	2273	1411	1122	1245	1589
29-Aug-88	2148	1692	1276	1192	1424
30-Aug-88	2263	1660	1716	1272	1287
31-Aug-88	2520	1238	1321	1120	1305
01-Sep-88	2189	1488	1516	991	1287

DATE	NAV	OTS	BLE	RBN	ELD
02-Sep-88	2254	1250	1214	1149	1482
03-Sep-88	2391	1290	1671	1273	1510
04-Sep-88	2290	1334	1507	1245	1397
05-Sep-88	2260	1440	1872	1358	1657
06-Sep-88	2342	1534	1509	1311	1511
07-Sep-88	2295	1998	1450	1440	1708
08-Sep-88	2330	1758	1888	1119	1850
09-Sep-88	2271	1534	1660	1435	2902
10-Sep-88	2318	1764	1787	1450	1947
11-Sep-88	2289	1311	1933	1383	1730
12-Sep-88	2338	1664	926	1430	1633
13-Sep-88	2328	1558	1625	1447	1653
14-Sep-88	2287	1384	1783	1443	1598
15-Sep-88	2461	1612	1117	1229	1791
16-Sep-88	2305	1772	2000	1498	1849
17-Sep-88	2323	1139	2079	1573	1946
18-Sep-88	2378	1599	1861	1500	1927
19-Sep-88	2219	1675	1859	1060	1890
20-Sep-88	2342	1514	1905	1670	1514
21-Sep-88	2313	924	1849	864	1673
22-Sep-88	2318	1638	1136	1385	1419
23-Sep-88	2544	1312	1619	1317	1872
24-Sep-88	2589	1548	1978	1194	1751
25-Sep-88	2462	1779	1811	1548	1839
26-Sep-88	2534	1349	1725	1498	1803
27-Sep-88	2473	1412	1810	1583	1326
28-Sep-88	2588	1557	2191	1129	1755
29-Sep-88	2340	1185	2007	1454	1770
30-Sep-88	2411	1625	2039	1569	1786
01-Oct-88	2336	1663	1990	1509	1537
02-Oct-88	2484	1713	1769	1535	1783
03-Oct-88	2567	1914	1943	1512	1715
04-Oct-88	2623	1495	2052	1162	1390
05-Oct-88	2802	1543	1662	1295	1581
06-Oct-88	2625	1290	1489	1443	1494
07-Oct-88	2490	1446	1658	1258	1612
08-Oct-88	2404	1681	1665	1429	1669
09-Oct-88	2439	1613	1479	1420	1611
10-Oct-88	2439	1683	1666	1380	2034
11-Oct-88	1575	1235	1915	1055	1283
12-Oct-88	862	635	806	849	1048
13-Oct-88	702	223	233	290	279
14-Oct-88	667	709	1170	668	819
15-Oct-88	1603	580	758	1448	638
16-Oct-88	2394	1112	1474	1402	1765
17-Oct-88	2549	1573	1951	1471	1698
18-Oct-88	2217	1112	1430	1412	1726
19-Oct-88	2324	1241	1783	897	1589
20-Oct-88	2243	1400	1421	1423	1604

DATE	NAV	OTS	BLE	RBN	ELD
21-Oct-88	2271	1706	2171	1583	1657
22-Oct-88	2239	1460	1848	1280	1477
23-Oct-88	2431	1560	1340	1317	1379
24-Oct-88	2273	1203	1365	1369	1493
25-Oct-88	2077	1247	1718	1145	1610
26-Oct-88	2892	1103	1106	1071	1297
27-Oct-88	2381	1584	1920	1496	1565
28-Oct-88	2211	1299	1873	1512	1324
29-Oct-88	2076	1421	1879	1565	1846
30-Oct-88	2234	1491	1933	1542	1839
31-Oct-88	2053	1653	1674	1596	1669
01-Nov-88	1961	7655	1480	1580	1458
02-Nov-88	2205	1314	1993	1491	1240
03-Nov-88	2105	901	1858	1330	1701
04-Nov-88	2219	1117	2323	1290	1714
05-Nov-88	2249	1525	1773	1540	1691
06-Nov-88	1569	1608	2024	1419	1921
07-Nov-88	2889	1149	1962	1532	1872
08-Nov-88	2231	1513	1983	1449	1779
09-Nov-88	2168	1210	1597	1492	1746
10-Nov-88	2138	1643	1964	1198	1692
11-Nov-88	2177	1508	1999	1380	1780
12-Nov-88	1999	1492	2102	1603	1618
13-Nov-88	2111	1978	2032	1557	1743
14-Nov-88	2051	1641	1225	1645	1931
15-Nov-88	2088	1506	1569	2589	1408
16-Nov-88	2040	1401	1834	2552	1209
17-Nov-88	2040	1328	1835	1266	1572
18-Nov-88	2164	1573	1244	1149	1623
19-Nov-88	2080	1383	1763	1508	1774
20-Nov-88	2169	1010	1635	1436	1633
21-Nov-88	2287	1015	1504	1436	1806
22-Nov-88	1953	1332	1004	1390	1577
23-Nov-88	2151	1362	1338	1416	976
24-Nov-88	2097	1546	1011	1461	1452
25-Nov-88	2172	1541	1717	1354	1567
26-Nov-88	2316	1414	1304	1211	1554
27-Nov-88	2140	1578	1305	1252	1486
28-Nov-88	2057	1384	1777	1267	1399
29-Nov-88	2150	1299	917	1164	1238
30-Nov-88	2192	1371	1586	1282	1378
01-Dec-88	2024	1274	1209	1234	1413
02-Dec-88	2097	1530	1455	1457	1503
03-Dec-88	2066	1485	1127	1401	1572
04-Dec-88	2009	1476	1362	1434	1750
05-Dec-88	2158	1521	1410	1329	1706
06-Dec-88	2046	1090	1662	1349	1266
07-Dec-88	2109	1483	1619	1917	1695
08-Dec-88	2075	1413	1112	1891	1594

DATE	NAV	OTS	BLE	RBN	ELD
09-Dec-88	1970	1282	1402	1290	1461
10-Dec-88	2073	1000	1340	1585	1352
11-Dec-88	1895		1684	1409	1622
12-Dec-88	1995	730	1734	1003	1485
13-Dec-88	2127	1498	1842	1447	1045
14-Dec-88	2062	1387	1426	956	1443
15-Dec-88	2158	1427	1006	1047	1408
16-Dec-88	2217	979	1843	1260	1489
17-Dec-88	2221	1449	1761	2157	1224
18-Dec-88	2120	1533	1701	1902	1505
19-Dec-88	2061	1577	1223	929	1385
20-Dec-88	2087	1156	1777	1295	1500
21-Dec-88	2098	1655	1651	943	1482
22-Dec-88	2096	1157	1667	1390	1441
23-Dec-88	2156	1340	1879	2451	1514
24-Dec-88	2197	1665	1814	2238	1574
25-Dec-88	2151	1794	2028	2402	1641
26-Dec-88	2248	1556	1915	1631	1507
27-Dec-88	2012	1333	1001	1202	1396
28-Dec-88	2107	1733	1687	1058	1450
29-Dec-88	2387	1494	967	1407	1464
30-Dec-88	2041	1340	1916	1439	1429
31-Dec-88	2231	1489	1833	1252	1396

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VITA

Captain Kenneth R. Norton [redacted] He graduated from Braintree High School in June 1978 and entered the Massachusetts Maritime Academy for one year. In June of 1979 he entered the United States Air Force Academy. While at the Air Force Academy he boxed and was the wing runnerup in the 185 weight class his senior year. He graduated from the Air Force Academy with a Bachelor of Science degree in Mathematics in June 1983. Captain Norton was assigned with the North American Aerospace Defense Command, United States Space Command, and Air Force Space Command from July 1983 to April 1989. During this period, he worked as an Orbital Analyst, Orbital Analyst Instructor, and Space Surveillance Center Commander Instructor in the Space Surveillance Center. He was responsible for developing the training program for two combat positions while remaining crew qualified in both positions. He has earned Space Command's skilled and expert awards. In May 1989, Captain Norton entered the School of Engineering, Air Force Institute of Technology at Wright-Patterson Air Force Base, Ohio.

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13. ABSTRACT *(Maximum 200 words)*

The relationship between the size of the United States Air Force Space Command's lost satellite lists and thirteen other variables is investigated. The thirteen variables contain the Space Surveillance Center crew's effort to work the lost list, solar activity, geomagnetic field strength, and the number of observations received each day from seven space track sensors. To identify the relationship of cause and effect between the lost lists and the thirteen variables, simple and multiple linear regressions are used on a data set that begins on 1 January 1988 and ends on 31 December 1988. Multiple linear regression and basic time-series smoothing techniques are used to forecast the number of lost satellites.

The results of this study show that solar activity causes near earth satellites to "go lost". This study also shows that not all sensors respond to increases in the size of lost lists in the same manner. Finally, the best forecast for the size of the lost satellite lists is provided by a multiple linear regression.

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