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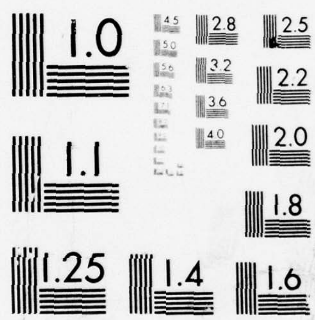

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Technical Note 1979-24

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Correlation Techniques for Deep Space "Uncorrelated Targets"

13 March 1979

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

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Group 91

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LEXINGTON MASSACHUSETTS

CONTENTS

1. INTRODUCTION

The Millstone Hill radar has been functioning as a contributing sensor for the deep space segment of SPACETRACK since February 1975. In addition to collecting metric data on known targets in deep space (above 10,000 km altitude), Millstone has been providing significant support to the Deep Space Shop of the Space Defense Center in the areas of orbital analysis and target motion analysis. The development of techniques for orbital analysis of "uncorrelated targets" (UCTs) represents an important contribution. Such a target is presently defined whenever a track fails to be matched with an object in the current catalog. If such a designated UCT is subsequently identified and matched with other tracks of a known object, we shall say that it has been "correlated." It is important to minimize the number of UCTs regularly carried in the system in order to aid recognition of genuinely new objects. This note covers the work on correlating UCTs.

1.1 The Satellite Tracking Network

The deep space SPACETRACK network of the North American Air Defense Command consists of several radars and optical sensors whose primary role is detecting and tracking satellites in high altitude orbits. The major elements of this network are the NAVSPASUR radar fence, the FPS-85 radar, the Millstone Hill radar, the ETS optical surveillance telescope in New Mexico, and several Baker-Nunn cameras.

The Naval Space Surveillance radar is a thin zenith fence distributed along a great circle across the continental United States at approximately 30°N latitude. The fence extends from about 35°W to 130°W longitude, and it detects satellite penetrations by interferometric techniques. Current power and receiver sensitivity limitations restrict detections to satellites within a maximum altitude of about 12,000 km at the fence.

The FPS-85 is a phased array radar located at Eglin Air Force Base in Florida. The surface on which the array elements are mounted faces south and is inclined at 45° to the ground. The beam can scan a cone with a half-angle of 60° about the normal to the face. Two fences are constantly monitored by the radar, one at low elevation for detecting SLBM launches and one at a higher elevation for satellite detection. Any satellite detected is also tracked for as long as it remains within the cone of visibility (a few seconds to a few minutes, typically).

The ETS electro-optical facility at the White Sands Army Base in New Mexico is a Lincoln-developed satellite surveillance, detection, and tracking system using four telescopes (two 31-inch mirrors and two 14-inch mirrors). Satellites reflecting sunlight are rendered detectable at night by their motion against the star background. The actual detection is made by MTI techniques with background subtraction or by the keen eyes of a human operator watching a live video display. ETS concentrates on deep space satellites (arbitrarily defined as having orbital period >500 minutes).

There are several Baker-Nunn cameras distributed around the globe. These operate by exposing film at a series of positions in the sky where satellites are expected. On later processing, a satellite can be detected by its streak against the star background (or conversely). The Baker-Nunns track deep-space satellites only.

Since February 1975, the Millstone Hill radar has been an active participant in the SPACETRACK network. The capability to detect and track deep-space satellites by coherent processing techniques has resulted in a substantial contribution by Millstone to the early orbit determination and catalog maintenance functions of SPACETRACK.

1.2 The Uncorrelated Target Phenomenon

The surveillance fences of SPACETRACK routinely attempt to match any object in track with the comprehensive locally maintained satellite catalog. Whenever such a correlation attempt fails, the object in track is labelled as an uncorrelated target (UCT).

The FPS-85 produces the largest number of UCTs in the system, 40-60 UCTs per day! Obviously, there are not really that many new targets. Typically, 5-10 of these UCTs lie in the deep space category. This surfeit of UCTs results from two phenomena:

1. The correlation bounds used by the FPS-85 are very tight, thus allowing too small an uncertainty in elements which may be poor.
2. The present FPS-85 software does not attempt to correlate a new UCT with similar objects from the past.

The first condition results in well-known targets (Skylab, standard Molniyas, etc.) being tagged as uncorrelated. The second phenomenon causes an explosive growth in the number of UCTs in the system. The FPS-85 assigns 5000 sequential numbers (90,000 to 94,999) to UCTs and then recycles these numbers, on average, once every 3-4 months.

The NAVSPASUR fence also detects uncorrelated targets. However, because of better software, the average is only 5-10 UCTs/day--and these are always correlated with previous penetrations of the fence by the same object.

The ETS electro-optical facility at White Sands Missile Range, New Mexico, has been detecting uncorrelated targets during searches of the synchronous belt. The combination of the 31-inch telescope with a 1° field-of-view and a moving target indicator has demonstrated excellent night-sky surveillance capability. The uncorrelated targets found by ETS have been numbered 95XXX. Approximately 120 such targets have been found thus far.

1.3 Millstone Interest in UCTs

Millstone's support of the deep space tracking mission has involved both observation and analysis of deep space orbits. The problem of monitoring many uncorrelated deep space targets was thus of major concern. The solution to the problem was felt to be threefold.

The first step was to reduce the 5-10 deep space UCTs per day to a more manageable number. The techniques for this effort used catalog extension and sorting by orbital type.

The second step consisted of orbit determination and subsequent tracking. Sophisticated orbit-fitting techniques were required on site along with timely scheduling of tracking time at Millstone or another sensor.

Finally, there remained catalog assignment. This task demanded that UCT tracks be correlated and associated with a known launch in order to properly assign a catalog number.

Steps 1 and 2 have already been implemented at the Millstone Hill radar. Step 3 has been only partially implemented. An improved software package is being developed to complete the identification process. The results since the initiation of this work in May 1976 have been very encouraging. In cooperation with the Deep Space Shop of the Space Defense Center at NORAD, a considerable reduction in the number of uncorrelated targets has been achieved. Table I gives sample results.

2. CATALOG EXTENSION AND SORTING

2.1 The Millstone Extended Catalog

The primary contributor of uncorrelated targets in deep-space orbits is the FPS-85, which tags 5-10 such UCTs per day. It was evident that the regular SDC catalog must be extended to include these UCTs in order to make later correlation possible. The Space Defense Center catalog is not routinely augmented with these UCTs.*

The FPS-85 produces local orbital elements on every target it tracks. Millstone arranged with the FPS-85 to receive both the metric data and the elements on UCTs once a day.

The major data base at Millstone is the Master Object File. It contains orbital elements of all deep space satellites in the SDC catalog. Additionally, it contains object characteristics and tracking parameters that are relevant to the functioning of the radar.

It was decided to augment the MOF by including the UCTs received from all other sources. Further, in the case of the UCTs from the FPS-85, a local

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*The SDC catalog has recently been extended to include UCTs of significant cross section.

TABLE I

SAMPLE RESULTS (AS OF JUNE 1977) OF THE UCT HANDOFFS FROM FPS-85 TO MILLSTONE

Total number of handoffs since 1 Jan 76	350
Total number of distinct objects	175
Targets correlated with SDC catalog	35
Correlated UCTs ($\geq$2 passes) (added to Millstone catalog)	90
Uncorrelated targets (1 pass) (added to Millstone catalog)	50
Orbit fits at Millstone	20
Tracked by Millstone	15
Number of objects added to SDC data base	50

numbering scheme was adopted whereby all objects with 9XXXX numbers which might subsequently be correlated could be mapped into a single Millstone number. The numbering scheme is given in Table II. The extended catalog has been operational since August 1976.

2.2 Sorting of UCTs

The orbital elements received from the FPS-85 (and other sources) are initially added to the data base with the object number supplied. The next step is to sort the entire extended catalog by orbit type. To this end, a sorting program was built as an overlay segment in the general purpose ASTEP* (Aid to Satellite Tracking and Ephemeris Prediction) software package available at the site.

The important concept used in this sorting technique is that UCTs in the extended catalog should be matched by orbit type rather than by their positions in space. Typically, the actual position of a satellite as calculated from its orbital elements can be in error by the equivalent of several seconds to several minutes of time. The magnitude of the error depends on the type of orbit, the accuracy of the orbit propagation software, and the frequency of observation. However, the orbit plane, defined by the inclination and the right ascension of the ascending node, evolves very slowly and hence can be used for correlation purposes. Further, the argument of perigee and the mean motion of the satellite serve as additional parameters to correlate objects. Thus using a combination of these four elements provides a powerful means of matching UCTs with satellites already in the catalog.

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*ASTEP has been replaced recently by a program called STARS which has a more extensive sorting capability.

TABLE II

MILLSTONE INTERNAL UCT NUMBERS

If a UCT is found to be a new object, it is assigned a Millstone 4XXXX internal number in a specific band corresponding to its inclination, namely

Band	Inclination
40000-40999	0°-20°
41000-42999	20°-30°
43000-43999	30°-60°
44000-44999	60°-70°
45000-45999	>70°

The sorting program has both interactive and automatic modes. When sorting is initiated, the orbital elements of all satellites in the data base are updated to a user-defined time. Then, in the interactive mode, the user can specify bounds on inclination (INCL), right ascension of the ascending node (RAN), argument of perigee (ARGP) and mean motion (MMOT). The updated catalog will be scanned and all objects whose elements lie within all the bounds specified will be printed out for analyst examination. An example is given in Fig. 1.

An automated mode also exists that is very efficient. The object numbers of the UCTs are set into a "map" list. Then, by invoking the automatic (AUTO) feature, each of the objects in the map is sorted against the updated catalog using bounds on the elements preset in the software. The preset bounds for the elements are given in Table III.

An example of the results of automatic sorting is given in Fig. 2, which illustrates the problem of tight correlation bounds at the FPS-85. Object 5986 had a well-maintained element set epoched on day 126. The FPS-85 tracked the object on days 128 and 132 and tagged it successively as two different uncorrelated targets (UCT nos. 93897 and 94347). The reason is that the FPS-85 compares the observed position at the time of track with the calculated positions of all satellites in the catalog. Tight bounds demanded that the position of the satellite in its orbit be known very accurately. However, the orbit propagation models used at the FPS-85 permit the error in calculated position, as represented by the time offset, to be large.

18-9-6644

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INTERACTIVE COMMANDS

    SORT SET      14    16    276    12     1976
    SORT INCL     26    27    RAN    256    276    MMOT    2.38    2.58
    SORT ARGP     344   384   GO

PROGRAM OUTPUT

    SORT COMPUTED FOR:
    INCLINATION BETWEEN 26.0 AND 27.0 DEG.
    RIGHT ASCENSION BETWEEN 256.0 AND 276.0 DEG.
    ARGUMENT OF PERIGEE BETWEEN 344.0 AND 384.0 DEG.
    MEAN MOTION BETWEEN 2.38 AND 2.58 REV/DAY
    FOR DAY 276 HOUR 12.00 YEAR 1976

    OBJNO     INCL     RAN      ARGP    MMOT
     94590    26.54    266.78   3.56    2.481
     91763    26.57    266.85   3.35    2.478
     90823    26.50    266.44   4.03    2.481

SORT COMPLETED    3 OBJECTS SATISFY STATED CRITERIA
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Fig. 1. Example of interactive mode of sorting program.

TABLE III

AUTO-SORT ELEMENT BOUNDS

The sorting bounds are offset from the current orbital elements of the chosen satellite as follows:

±.5° in inclination

±2° in the right ascension of the ascending node

±5° in argument of perigee

±.15° rev/day in mean motion

The bounds are automatically enlarged for low inclination (<1°) and high inclination (>60°) orbits.

18-9-6645

AUTO-SORT PERFORMED USING OBJECT 93897 WITH BASE VALUES OF:

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
93897	26.38	33.99	39.42	2.496	128

INCLINATION BETWEEN 25.9 AND 26.9 DEG.
RIGHT ASCENSION BETWEEN 32.0 AND 36.0 DEG.
ARGUMENT OF PERIGEE BETWEEN 34.4 AND 44.4 DEG.
MEAN MOTION BETWEEN 2.346 AND 2.646 REV/DAY
FOR DAY 135. HOUR .00 YEAR 1978

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
5986	26.36	33.96	39.42	2.496	126
94347	26.38	33.99	39.49	2.502	132

SORT COMPLETED 2 OBJECTS SATISFY STATED CRITERIA

Fig. 2. UCTs produced by tight correlation bounds at FPS-85.

2.3 Correlation of UCTs by Sorting

The obvious next step is to determine which of the candidate catalog objects (if any) provide a UCT correlation. All the data for this object can then be combined. The process is quite vividly illustrated by Figs. 3-6.

At present (and probably in the future too) there is no automatic mode for such correlation: an analyst's decisions are required.

Fig. 3 illustrates the process of augmenting the resident satellite catalog. UCT no. 94375 was tracked by the FPS-85 on day 133, 1978. An automatic sort against the Millstone catalog found two candidates within acceptable bounds; but the large differences in the values of RAN and ARGP indicated a new object was at hand. Hence, the analyst invoked a "COMBINE" feature that

1. assigns a new local Millstone number consistent with Table II,
2. writes the orbital elements received from the FPS-85 into the catalog under the above number, and
3. creates other informative cards for the object using a set of default values.

An automatic sort on object 94436, tracked by the FPS-85 on day 133, 1978, is shown in Fig. 4. The correlation of 94436 with the object numbered 41141 (internal Millstone catalog number) is evident; the process of combination replaced the old elements of 41141 by the new elements of the UCT. Object 94436 was then deleted from the catalog.

Figs. 5 and 6 illustrate dramatically the correlation capability at Millstone. Object 41000 was received as a UCT on day 166, 1977. Since then, no other UCT matched with 41000 until day 133, 1978. Despite the 332 days

18-9-6646

AUTO-SORT PERFORMED USING OBJECT 94375 WITH BASE VALUES OF:

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
94375	26.99	154.65	13.42	2.337	133

INCLINATION BETWEEN 26.5 AND 27.5 DEG.
RIGHT ASCENSION BETWEEN 152.6 AND 156.6 DEG.
ARGUMENT OF PERIGEE BETWEEN 8.4 AND 18.4 DEG.
MEAN MOTION BETWEEN 2.187 AND 2.487 REV/DAY
FOR DAY 135. HOUR .00 YEAR 1978

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
41030	26.95	153.35	15.61	2.380	122
94044	26.91	153.32	15.65	2.382	130

SORT COMPLETED 2 OBJECTS SATISFY STATED CRITERIA

ANALYST COMMAND	PROGRAM ACTION
COMBINE LL 94375	A NEW ENTRY, 41031, WAS CREATED IN THE MOF WITH THE ELEMENTS OF 94375 AND ADDITIONAL INFORMATIVE ENTRIES
DELETE 94375	THE ENTRY OF 94375 WAS ERASED FROM THE MOF

Fig. 3. Example of augmenting the catalog (MOF).

18-9-6647

AUTO-SORT PERFORMED USING OBJECT 94436 WITH BASE VALUES OF:

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
94436	26.73	356.75	342.54	2.708	133

INCLINATION BETWEEN 26.2 AND 27.2 DEG.
RIGHT ASCENSION BETWEEN 354.7 AND 358.7 DEG.
ARGUMENT OF PERIGEE BETWEEN 337.5 AND 347.5 DEG.
MEAN MOTION BETWEEN 2.558 AND 2.858 REV/DAY
FOR DAY 135. HOUR .00 YEAR 1978

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
83725	26.67	357.15	346.00	2.698	114
41166	26.53	357.77	344.80	2.710	-36
41141	26.75	356.77	342.50	2.706	106
41018	26.63	355.63	347.10	2.657	104
93880	26.63	357.06	346.22	2.708	128
94214	26.63	357.08	346.13	2.708	131

SORT COMPLETED 6 OBJECTS SATISFY STATED CRITERIA

ANALYST COMMAND	PROGRAM ACTION
COMBINE 41141 94436	THE ORBITAL ELEMENTS OF UCT 94436 REPLACE THE CURRENT ELEMENT SET IN THE ENTRY FOR 41141 IN THE MOF
DELETE 94436	THE ENTRY FOR 94436 IS DELETED FROM THE MOF

Fig. 4. Correlation of UCT with existing entry in the MOF.

18-9-6648

AUTO-SORT PERFORMED USING OBJECT 94390 WITH BASE VALUES OF:

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
94390	26.16	196.00	7.67	2.572	133

INCLINATION BETWEEN 25.7 AND 26.7 DEG.
RIGHT ASCENSION BETWEEN 194.0 AND 198.0 DEG.
ARGUMENT OF PERIGEE BETWEEN 2.7 AND 12.7 DEG.
MEAN MOTION BETWEEN 2.422 AND 2.722 REV/DAY
FOR DAY 135. HOUR .00 YEAR 1978

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
41000	26.59	196.70	5.92	2.570	–199

SORT COMPLETED 1 OBJECTS SATISFY STATED CRITERIA

Fig. 5. Correlation of UCT with a long-lost object in the Millstone catalog.

18-9-6649

AUTO-SORT PERFORMED USING OBJECT 94477 WITH BASE VALUES OF:

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
94477	26.32	327.60	157.98	2.633	133

INCLINATION BETWEEN 25.8 AND 26.8 DEG.
RIGHT ASCENSION BETWEEN 325.6 AND 329.6 DEG.
ARGUMENT OF PERIGEE BETWEEN 153.0 AND 163.0 DEG.
MEAN MOTION BETWEEN 2.483 AND 2.783 REV/DAY
FOR DAY 135. HOUR .00 YEAR 1978

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
83669	26.45	327.92	157.63	2.632	-24

SORT COMPLETED 1 OBJECTS SATISFY STATED CRITERIA

Fig. 6. Correlation of UCT with long-lost object in the SDC catalog.

difference, the sorting program was able to present the information in Fig. 5 to the analyst; the analyst was able to recognize the correlation and combine the two object numbers. A very similar result is shown in Fig. 6, where a gap of 157 days did not prevent correlation of UCT 94477 with SDC object 83669.

2.4 Special Applications of Sorting

There are two major operational applications which demonstrate the power of the sorting software at the site.

On nearly every launch of a synchronous satellite from the Kennedy Space Center, a rocket body is left in a deep space orbit, generally a high-eccentricity transfer trajectory. After separation of the payload, the rocket body performs a collision avoidance maneuver (CAM) that puts it into an orbit with a higher period than the transfer trajectory of the satellite. However, the total fuel burnt in the CAM is usually not well determined. Thus, the element set postulated for object is rarely correct and it is usually lost for a while. (These transfer trajectories do not have an orbital period which is a submultiple of a day; hence the sublongitude of the perigee of the orbit drifts.) Typically, 5-10 days after launch, the FPS-85 tracks the object and it is tagged as an uncorrelated target.

Results of sorting the UCTs against the catalog alert the analyst who is aware of the lost rocket body, and he can usually effect a correlation. Fig. 7 is an example of the rocket body 83185 being picked up as a UCT.

The second, more general, area of application is that of lost deep space satellites. Occasionally, due to vagaries of weather, tasking, and satellite visibility, a satellite may not be tracked for several weeks or even months.

18-9-6650

AUTO-SORT PERFORMED USING OBJECT 94482 WITH BASE VALUES OF:

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
94482	28.53	359.72	206.10	2.453	133

INCLINATION BETWEEN 28.0 AND 29.0 DEG.
RIGHT ASCENSION BETWEEN 357.7 AND 361.7 DEG.
ARGUMENT OF PERIGEE BETWEEN 201.1 AND 211.1 DEG.
MEAN MOTION BETWEEN 2.303 AND 2.603 REV/DAY
FOR DAY 135. HOUR .00 YEAR 1978

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
83185	28.53	359.77	205.98	2.426	120

SORT COMPLETED 1 OBJECTS SATISFY STATED CRITERIA

Fig. 7. Correlation of UCT with previously untracked satellite (94482 = 83185).

By then, the element set is too old and the orbit propagation model too imprecise to permit direct reacquisition of the object. Quite often, in such cases, a surveillance fence like NAVSPASUR or FPS-85 finds and tracks the object as a UCT. The sorting program at Millstone results in correlation with the lost object. An example is provided in Fig. 8. Object 4298 is the deep space rocket body of Intelsat 3F-6, launched on 15 January 1970. It was last tracked on day 64, 1978, after which no sensor detected or tracked the object as such. However, on day 129 and again on day 134, the FPS-85 tracked UCTs that Millstone sorting correlated with 4298. Thus, the object was retrieved and a fresh element set generated.

2.5 Correlation of UCTs by Orbit Determination

The examples in Sections 2.3 and 2.4 assumed that orbital elements for the uncorrelated target were available from external sources (FPS-85, SPASUR, etc.). However, Millstone does have the capability to accept metric data from any other sensor, fit an orbit to the data, generate elements, and then sort through the catalog for a possible correlation. Obviously, such a mode is not automatic but involves an analyst. The process is illustrated below by actual examples.

During a search for LES-6 on 5 November 1977, the Millstone Hill radar detected and tracked an object. However, the orbit fitted to the 10 points of metric data produced during a 15 minute track had a substantially higher inclination--of about 7° instead of 4.8° for the LES-6 orbit. Hence further tracks of the object were made by both Millstone and ETS. The resulting orbit was near-circular with inclination of 7°, right ascension of the ascending

18-9-6651

AUTO-SORT PERFORMED USING OBJECT 93992 WITH BASE VALUES OF:

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
93992	27.75	237.18	242.83	2.379	129

INCLINATION BETWEEN 27.3 AND 28.3 DEG.
RIGHT ASCENSION BETWEEN 235.2 AND 239.2 DEG.
ARGUMENT OF PERIGEE BETWEEN 237.8 AND 247.8 DEG.
MEAN MOTION BETWEEN 2.229 AND 2.529 REV/DAY
FOR DAY 135. HOUR .00 YEAR 1978

OBJNO	INCL	RAN	ARGP	MMOT	EPOCH
4298	27.85	237.62	242.46	2.376	64
94552	27.64	237.15	242.84	2.382	134

SORT COMPLETED 2 OBJECTS SATISFY STATED CRITERIA

Fig. 8. Correlation of UCT with lost rocket body (93992 = 4298).

node of 54°, and mean motion close to synchronous with a drift rate in sub-longitude of 11.8 deg/month westward. Sorting against the SDC catalog elicited no correlation candidates. However, comparison with a list of aging Instelsat satellites showed conclusively that the satellite was Intelsat 2F2.

Another example pertains to a UCT that was detected and tracked by ETS on 14 October 1977. Metric data spanning 1.2 hours were sent to Millstone. Orbit fitting at Millstone indicated that the object was in a trans-synchronous orbit with inclination of 6°. ETS reacquired and tracked the target on 15 and 16 October using the orbital elements supplied by Millstone. Processing of all the data indicated a satellite in a plane inclined to the equator at 6.1°, with right ascension of the ascending node of 52° and a drift rate of 36.2 deg/day westward in sublongitude. Again, attempts at direct correlation with the SDC catalog yielded no results. However, it was known that at the end of May 1977, a few Instelsat 3 series satellites had been maneuvered into trans-synchronous dead-storage orbits. These satellites had subsequently been lost. Comparison with the Intelsat elements indicated that the satellite tracked by ETS was in all probability Intelsat 3F4.

The procedure of orbit estimation, sorting, and correlation is now routinely applied at Millstone on all UCTs from ETS.

3. CURRENT STATUS

Most of the work described in Sections 1 and 2 was done between May 1976 and early 1978. The current status of the extended Millstone catalog, broken down by inclination bands, is given in Table IV. The number of tracked but unassociated targets is still quite large and the resulting catalog lists over 900 objects.

TABLE IV

STATUS OF THE MILLSTONE EXTENDED CATALOG OF DEEP SPACE OBJECTS

Inclination Limits	Number of Objects
0°-10°	189
10.001°-20°	21
20.001°-30°	340
30.001°-40°	3
40.001°-50°	30
50.001°-60°	12
60.001°-70°	303
70.001°-80°	8
80.001°-90°	3
90.001°-180°	5
TOTAL	914

(Satellites included above have mean motions <4 revs/day)

Since the beginning of this work, a new Harris S220 has replaced the SDS 9300 as the primary computer supporting the radar measurements and the data analysis. All the sorting facilities of ASTEP have been transferred to the Harris and incorporated into a new program, STARS (SATTRK Tracking and Reporting System), which also contains other new features. The data-base management features of ASTEP are now carried out by the SATTRK System Supervisor (SUPVSR), a resident real-time program on the Harris which is responsible for updating the Master Object File.

4. SUMMARY AND FURTHER WORK

The techniques developed at Millstone and discussed in this note have contributed in a major way to the resolution of problems with uncorrelated deep-space targets.

An extended catalog has been developed at Millstone that includes the entire SDC deep space catalog and all the UCTs received from all sources. The orbital elements of any new UCT are sorted for matches with all objects in this extended catalog. Among those matches, if a correlation can be found, the objects are merged into one catalog entry. The growth rate for the number of UCTs has thus been sharply reduced.

Orbit-fitting software at Millstone is used to generate elements on objects when only metric data are available. Identification of a UCT with a specific launch or satellite (association) is achieved by significant analyst interaction using all sources of information available.

Obviously, not all UCTs in the Millstone catalog have yet been identified with specific launches. This task is the major area for future work. Two supporting items are needed:

1. An efficient and accurate analytic orbital determination and orbit propagation program. This is currently being developed.*

2. A data-base processing algorithm that flags missing entries in the extended deep space catalog and generates nominal orbital elements for these missing objects. No work has yet begun on this.

Another area of applicability of the work reported here is in the low altitude regime. The number of uncorrelated targets in low altitude orbits is also quite large. All the techniques described for deep space UCTs in this note can be extended to the problem of low altitude UCTs also.

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*W. P. Seniw and R. Sridharan, "ANODE: An Analytic Orbit Determination System," Lincoln Laboratory, M.I.T., Technical Note 1979-26, to be published.

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The surveillance fences of SPACETRACK detect and track a large number of space objects that do not correlate with known objects in the satellite catalog. This note describes the techniques developed at the Millstone Hill Radar for the analysis of these uncorrelated targets.

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