Final Report

# SUBOPTIMAL FILTERING

## Part 4:

## TEST-BED COMPUTER PROGRAM

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## FOREWORD

This final report is in four parts:

Part 1: ADAPTIVE FILTERING

Part 2: COMPENSATION FOR MODELING ERRORS IN ORBIT DETERMINATION PROBLEMS

Part 3: LIMITED MEMORY OPTIMAL FILTERING

Part 4: TEST-BED COMPUTER PROGRAM

The first three parts describe several suboptimal filter concepts developed under this Contract. A number of these filters have been simulated in the rectilinear orbit problem. These simulations are described therein. In order to provide a more realistic environment for testing these suboptimal filters, a more general test-bed computer program is under development. This program enables the simulation of real observation schedules and combined effects of dynamical model errors in three-dimensional satellite motion. This program is briefly described in Part 4.

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TEST-BED COMPUTER PROGRAM

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## PROGRAM DESCRIPTION IN-BRIEF

This computer program consists of two decks. 6D-Part 1 generates an observation tape which is processed by the filters in 6D-Part 2.

### 6D-Part 1 : Generates Observations

This program accepts a real observation tape and generates simulated observations on the basis of the times and observation types corresponding to the real data. The simulated orbit (three-dimensional) contains real-world error effects which are superimposed on two-body motion via the theory described in Reference [1]. The output of this program is an observation tape which is input to 6D-Part 2.

Read from the real observation tape are times in hours from 1960.0, the observation types (range, range rate, $\ell$ and m direction cosines), and the station numbers. Input required includes initial range (R) and range rate ($\dot{R}$) vectors (in km and km/sec, resp.), and initial time in years, days, hours, minutes and seconds. R and $\dot{R}$ are converted to earth radii and earth radii per hour, and all computations are performed in these units.

The program reads the real observation tape and updates R and $\dot{R}$ to the time of the (next) observation. The updating is performed either by two-body theory [input NC(72) = 1 ], or by rotating conic theory of Ref [1] [input NC(72) = 6 ].

Following the update, if NC(71) = 1, six independent Gaussian noise samples are added to each of the six state (position and velocity) components.

The noise distributions are zero-mean with variances VARX(I), I = 1,6. This section is skipped if NC(71) = 0.

The appropriate observations are then computed for that time. Observation types are labeled by NTYPE. Zero-mean, independent, Gaussian noise samples with variances RVAR(NTYPE) are generated and added to the observations.

An observation tape is generated.

The first record on the tape contains the initial conditions, the number of stations, the noise variance in each observation type, and several parameters for each station which are functions of the stations' latitude, longitude and altitude. We assume that the stations are on a spherical, rotating earth.

Each successive record contains:

Time in hours from 1960.0 of the observation;
Greenwich siderial time;
Station number;
Observation type number: range = 3, range rate = 4, $\ell = 7$, m = 8;
The noisy observation;
True R and $\dot{R}$ .

6D-Part 2: Filters

This program accepts the observation tape generated by 6D-Part 1, and stores the records on that tape in a table numbered from 1 to NTTMX, NTTMX ≤ 1500. Time is now referenced to an initial time of zero.

Depending on input, the program will process the observations via any or all of the following (currently available) filters:

Filter No. 1: Kalman filter

Filter No. 2: Limited Memory filter (see Part 3 of this report)

Filter No. 3: Exact filter (optimal for the system noise case)

Filter No. 4: Adaptive filter (uses estimator (27) of Part 1 of this report).

The dynamics in all the filters are two-body dynamics, which do not take into account the model error effects included in the true orbit.

Printed after each observation are the filter number and estimation errors $(x_i - \hat{x}_i)$, their predicted variances $P_{ii}$, and $(x_i - \hat{x}_i)/P_{ii}^{\frac{1}{2}}$ for each filter.

## References

[1] Samuel Pines, "On the Modeling of Real World Error Sources for Near-Earth Orbits," Analytical Mechanics Associates, Inc. report. Paper presented at NASA-GSFC Seventh Semi-Annual Astrodynamics Conference, April 16-17, 1968.