Detailed Scoring Rules

The scoring rules for the tables are described below. A few general comments are in order. Part way through the review, some of the vendors decided to withdraw. Items that are in curly braces {} are categories that we deemed important, but that none of the remaining vendors happen to cover. Two examples of times in curly braces are given here. First, none of the remaining vendors had unit test drivers for each function, a small program that tests each m-file function. We had scoring rules for how well the unit test drivers worked ("U" and "U-WD"). We still feel that vendors should supply a sub-directory of unit test drivers because users might alter the supplied functions. A well done unit test driver not only tests a few cases, but it would also test the error handlers by putting in all possible combinations of wrong inputs and showing how the supplied function handles them. A second example of an empty category that is now marked in {} is constants in Table 4.1. Ideally, the various constants should be implemented as global variables that you can centrally change, but all of the remaining vendors in the Oct 1998 review had hard-wired constants scattered about. So, the additional sub-categories within constants is now marked in {}.

In the first table, *Toolbox overview*, platforms, price, and the number of functions each product delivers are pretty much self explanatory. (Note that the tabulated disk space depends on the allocation block size being 32Kbytes. An optimized file-system with better block sizes will use substantially less space.) Technical support and copyright are then summarized. Copyright is important because engineers will want to use these packages for contract work. Most of the vendors have a standard policy of allowing you to use the results for contract work, but if you deliver your products to a customer with their code, you must then pay the purchase price for each CPU the code executes on. In terms of operation on other platforms, all of the vendor packages eventually executed on a MAC platform. However, the vendors could have been more careful about file-naming conventions so that minor adjustments were not needed. All had free support for the first year, but upgrade prices and quantity discounts were not established yet.

Table 2 covers *Organization and documentation*. To score a yes ("y") in the *purpose/problem* category, the manual must describe useful problems that you can solve with the package. To get a well done ("wd") score, a cross-reference table would have to be present showing which demo programs/functions solved specific application problems. The "y" in the *programming tutorial* category is present if there is a section that describes which functions to call to solve specific problems. A "wd" is added if block diagrams and other aids were present. The next section, *conventions*, will have a "y" entry if the package discussed standard implementation/programming practices that should be used when calling the various functions. For example, whether vectors are to be rows or columns, whether the SV index is the row or column dimension, and whether time is the row or column dimension etc. A "wd" is given if gaps, outages, and vectorization issues are discussed, or present in a read-me file and/or appendix. A "y" score is given to the *GPS theory* category if there is some academic discussion of GPS physics in any of the tutorials. For example, discussions on how de-correlated troposphere errors effect the integer phase ambiguity solution. The *calling tree* category gets a "y" score if there is a summary table showing which functions call other functions or if there are comments in each m file indicating other functions called. A "wd" is given if both criteria are met. A "y" is given to the *unit test* coverage if select routines have unit test drivers. A "wd" is given if the unit test drivers actually test boundary cases, mid-point cases, and error handling. The *on-line help* category has further sub-categories. Matlab supports users creating their own on-line help by following some simple rules. The three basic rules are: 1) the first series of unbroken comment lines will be displayed when the user types "help function_name" at the command prompt. Usually, you put the calling inputs, outputs, algorithm references, error conditions and example usage here; 2) the first comment line is special. If you put the function name in capital letters, a space, then a one line description along with buzz words, the user can at the command prompt type "lookfor keywords" and retrieve these one line summaries. This is a one line subject index to help you find out what arcane function name does what you want; 3) with proper formatting of the See-also comments about related functions, Matlab 5.x's html help desk will pick-up and use the information. Thus, in the category of *on-line help*, sub-category *Input/Outputs*, a "y" indicates i/o arguments are documented, and a well done is given if all special restrictions were correctly documented. A "y" is given to *algorithm references* if specific text books are referenced. A well done is given if all of the special restrictions are noted (such as: does/does not work in space geometry; when less than 4 SVs are present, we do the following) and if explicit page numbers in the references are given. Unfortunately, no one passed this test; corner cases may not be well

explained and it may be hard to find the page in the text book that was referenced. The next sub-category tests for whether the *contents.m* file is present summarizing all of the functions in a given sub-directory. A "wd" is awarded if the contents.m file contains all of the lookfor help lines, and is sorted by subject category the way Matlab's own contents.m files are done. The *Lookfor* sub-category gets a "y" if present. It gets a well-done if a good number of keywords and buzz words are present to make it effective. A "y" in the *see-also* category indicates that see-also comments are in the on-line help and a well-done if the they are html compatible. In the last category, *reference organization*, a "y" is given for each organizational index and table present. As mentioned earlier, all of the packages could use a subject cross-reference index and a general index.

Table 3 scores software *Implementation*. The first category in this table is *vectorization*. A "y" is given if vectorization is done with respect to either time or SV loops. A "wd" is given if both time and SV vectorizations are done. {A "y" in the *global control* section indicates you can direct all error messages to either the screen, a file or both. A "wd" is given if you can control the number of warnings and error messages that are output before going silent or terminating.} A "y" in the *error checks* category indicates that some type of standard error handling and input argument checking is done, a "wd" indicates that centralized functions are used to do these checks. A "y" in the *outage and gaps* section indicates that some type of well thought out convention is used for indicating data-gaps and a "wd" is if it also is used in the graphics area. A "y" in the *documenting tricks* entry is given if the code contains enough clues so that you can deduce the algorithm limitations. A "wd" is given if the vectorization specifics are explained also. This score is based on our sampling of the pseudo range and SA routines as representative spot checks. A "y" in the *chunking/memory* category indicates that there is a procedure that can be used to break up a large run, such as a 10 hour run, into smaller 1 hour chunks, each chunk being highly vectorized. A "wd" is given if the chunks don't have to be uniform in size and the file buffering, reading, and writing routines are provided. The *correct ECEF WGS-84* category means that the ECEF from latitude, longitude, altitude conversions obey WGS-84 rules. The last two categories cover *Platform and version control testing*. Essentially, as these packages evolve, they will have to maintain back compatibility, or do a test to see if old code is being used and warn the user that some functions have become obsolete. So, a "y" means that the package tests for which version of the functions it is calling, and also tests for which platform it is executing on (version of Matlab and platform). A "wd" is given if all of the above platform tests are smoothly integrated and consistent checking for the version of Matlab, Matlab platform, and version of the GPS toolbox your using.

Tables 4.1 through 4.6 cover the application problem areas for these packages. Each broad problem are is broken into several specific categories and myriad sub-categories in order to summarize how well the packages cover the vast domain of GPS simulation problems. The explicit scoring rules for each of these tables are given below:

Table 4.1 GPS scenario simulation – Problem 1

Constants category: A "y" is awarded if the WGS-84 and ICD-GPS-200 constants are *hard-wired* into the code. There is no well-done here because it is much preferred if GLOBAL variables are used so that any changes affect all modules. {The next set of sub-categories score whether the more popular datums such as *WGS84, WGS72, SGS-85, and PZ-90* were present. Only one package did. A well done was awarded if the different dataums could be mapped into one common set so that you could change the default operation from WGS84 to WGS72 or some other datum. A "UT" score was given if a test driver tested that the constants loaded correctly. A well done unit test would be awarded if the swapping of datums was tested. There are some other subtle points we looked for. ICD-GPS-200 specifies truncated versions of π and the speed of light. So, to score a yes in the truncated and true constant categories, the software should have the truncated constants used in almanac and ephemeris calculations (see *Satellite Orbit Tools* in Table 4.1), and the most accurate physical/math constants used in the truth model functions (*see Measurement Simulation* Tools in Table 4.1). Thus, the *physics and math* constants sub-categories are to be used for truth model math and physics variables, and *ICD-GPS-200 Physics and Math* takes care of all truncated versions of these, as well as any other GPS constants (such as L1 and L2 values).}

GPS coordinates: The minimum requirement is to have GPS *ECEF* (earth centered earth fixed), *ECI* (earth centered inertial), and (*LLA*) Latitude, Longitude, Altitude. A "wd" is given here if the ECI frame has some

option to tie it down to either an absolute Julian day or to let it float based on a user preference and if the angles for longitude and latitude are tested for valid input ranges. To get a "y" in the *local level* sub-category, North-East-Down, East-North-Up, or some local frame has to be present. A well done is given if both NED and ENU are present and the pole singularity is documented or avoided. The *wander azimuth* frame sub-category indicates that a local-level frame was implemented that avoids the North and South pole singularities. However, to get "y" in this area, both the forward and back transforms must be given. A well-done is awarded if it is properly documented and referenced. The *body-frame* sub-category is scored "y" if a nose, right-wing and down or some such body coordinate frame is present. A well done is given if the rotation angle ordering is documented and if vectorization conventions are present and documented. {The *antenna frame* sub-category is scored yes if present, and well done is given if the frame orientation can be varied with time.} Azimuth and elevation angles (*azi and elv*) get a "y" is they are at least calculated for the line-of-sight relative to a local level frame, and a well-done is given if the function is flexible enough to calculate azi and elv relative to either local level, body, or antenna frames. {The final two sub-categories involve coordinate frame routines that support *lever arms and angular rates* so that velocity and acceleration of the antenna phase center can be calculated. A "wd" is given for extensions for the jerk. The last category is given a "y" if all frames, lever arms, and center of mass are *functions of time* and a well done is given if the system can handle a space vehicle with stages that can fall off, fuel tanks that empty, and keeping track of multiple antennas on the various stages of the rocket.}

{ *Datum Tools*: A "y" in the first sub-category means that you can convert between *GLONASS and WGS84* data. A "wd" is given if you can do SGS-85 and PZ-90 datums. A "y" in the *DMA* means that you can purchase additional toolboxes to read DMA CD-ROM data-bases. A "y" in the *other* category means that you can purchase CD-ROM data for other commonly employed datums and interface with it.}

Time: To score a "y" in the *GPS time* category, the software must support specification of time in terms of a GPS week and time of week. A well-done score is given to a package that also has a documented way of specifying dates within the first 1023 and second 1023 week rollover period. The next sub-category covers whether there are functions to convert between *Julian* calendar dates and GPS time. A well-done is given to packages that handle multiple 1023 week epochs. *UTC to GPS* time conversion is scored. A well-done is given to packages that allow one to update the data-base of UTC offsets and give warning messages to the user when the data-base needs more data for the conversion being done. The next sub-category tests whether the time functions are *Y2K* (year 2000) compliant. Our Y2K software tests require that the Julian date function correctly calculate the leap day of Feb 29 in the year 2000. (In a hardware receiver, the real-time clock and Y code key management must correctly operate during Feb 29, 2000. For 1023 rollover tests, a hardware receiver must also track Y code through the 1023 roll-over and also the almanac 8 bit limit 256 week-rollovers must correctly work (see reference 7)). The last sub-category is mapping of *GPS time to simulation time*. A "y" indicates that a function is there to do it, a "well-done" indicates that vectorization and data-gaps can be handled in this mapping.

Satellite Orbit Tools: A "y" in the first sub-category score indicates that the package can create a typical constellation based on *circular orbits*. It is well done if an actual almanac is used with zero eccentricity. The next entry is for *almanac* based orbits. A "y" indicates if Yuma or SEM files can be processed. A "well-done" is assigned if the following three features are implemented: 1) the user may update individual SVs almanac entries in the middle of the run in order to simulate ground control uploads; 2) the user may evaluate the almanac as specified in reference 1, wrapping the difference between time and time of applicability to a ± _ week excursion; 3) the user may evaluate the almanac at times up to ± 6 months. This last feature is used to simulate a receiver undergoing a restart with stale almanac after being powered down for 6 months. A "y" in the *ephemeris* category indicates that real ephemeris data can be evaluated. A "well-done" requires that individual SV entries can be updated at different times in the run, or by segmenting a run into intervals where no updates are made. The *GLONASS circular* sub-category indicates whether approximate GLONASS SV orbits are implemented, and a well-done means that they are just special cases of real orbits. The *actual GLONASS* orbits require that full GLONASS algorithms be supported, and a well-done requires the simulation of uploads. {The SV *rotation* sub-category indicates whether the orientation of the SV is modeled so that circular polarization phase wrap-up effects (reference 8-9) can be simulated. A well-done requires that actual ground control thruster commands be used to orient the SVs.}

Trajectory Tools: To receive a "y", the package should at least be able to read a *file of positions and velocities* vs. time. A "well-done" is given to packages that support body angles so that body frame orientation can be simulated. The next sub-category rates whether additionally *acceleration and angular rate* data is supported. To get a "wd", book-keeping down to the third derivative of position (jerk) would be required. The next sub-category rates whether the package can *generate user motion files* from high level commands such as "turn left", "speed-up" etc. A well-done is assigned in this category if different personality files for auto, sea, air, and space-craft vehicles can be modeled. {Because re-useable software components and compatibility with existing standards is useful, a package that supports the reading and writing of *PROFGEN* from the Air-Force (reference 10) or *GPS RF Simulator* vendor trajectory formats gets a "y" if it can read and write these formats, and a "wd" if implements a compatible sub-set of the motion command language.}

{*User Antenna Tools*: To receive a "y" in the first sub-category, the package would have to an *antenna* coordinate frame and the ability to handle a 2D look-up table of antenna gain as a function of azimuth and elevation of the LOS relative to the antenna frame. A "well-done" is assigned to packages that support 2D look-up tables in some clever Matlab structure that allows for vectorization. The *phase and group delay* sub-categories have similar scoring criteria, but the outputs are phase shift and group delay. The next category is for antenna arrays which is a niche business opportunity. To score a "y", the package should allow the user to specify a set of *array* locations and complex weights. To score a well-done, the package should allow the weights to be functions of time so that the user can implement adaptive array algorithms. The next sub-category covers the effects of multiple antenna *biases and feed lengths* on the phase and prange data. To score a "y", the package should allow the parameters that are entered to affect the prange and phase data. To score a "y" in the *blockage* sub-category, the program should have a 2D look-table to determine block-age as a function of an antenna orientation. The final sub-category is to allow the user to *schedule* (as a function of discrete events), the antenna lever arm, orientation, and patterns to be used or to be summed together. A well-done scheduling would allow both fixed times and conditionals to be used based on the user writing their own trajectory segment function. For example, a segment function might connect antenna 1 to receiver 1 when the elevation angle is below a value and connect receiver 1 to antenna 2 for other times. Or, it may be a fixed mapping vs. mission time.}

Visibility and Masking Tools: A "y" in the first sub-category indicates that a simple *earth blockage* model for land-based systems is implemented using a local level mask. A well done is given if the book-keeping for the different causes of the blockages are stored so that blockage reason can be ascertained later. The next sub-category discusses vehicle blockage. A "y" indicates that *vehicle blockage* checks are done, a well-done is given if the various blockage factors for earth and vehicle are separately accessible. The next sub-category is scored with a "y" if all the models are space capable. A well done is given if they are vectorized. {The last category is *terrain masking*. A "y" is given if statistical models for terrain masking are implemented, and a well-done if a separate add-on package is provided to interface with CD-ROM databases.}

Measurement and Modeling Tools: The first sub-category checks whether the trivial function of *LOS range*, user position minus SV position, is calculated. A well done score indicated that range, velocity, were true integrals of the velocity and acceleration data (if the package generated the trajectory data). The next sub-category covers modeling of the *user clock and drift* problems. A "y" indicated that some type of model was present. A "well-done" score was given if the model had a) constant and bias terms, b) some Allan variance white and 1/f frequency noise terms that were transformed into approximate lumped models of noise as done in reference 4 page 428. {The next sub-category has a "y" if the almanac and ephemeris af0, af1. and af2 *SV clock error* terms are generated. A well done is scored if you can put one model into the satellite and have the simulated receiver using another set.}

NOTE: Many software packages mistakenly assume range plus user and satellite clock errors make up pseudo-range. Even with a perfect clocks, pseudo-range is not the same as range. The definition of pseudo-range, from reference 1, is: time at signal reception as measured by user clock minus time at transmission as measured by satellite clock. Thus range is the time interval of travel when the satellite and receiver are frozen at the same instant in time, while pseudo-range is the time interval of travel (with or without assuming perfect clocks). By the time the GPS receiver gets the signal (about 70 msec), the satellite has moved. Most receivers internally compensate for satellite motion propagation, but depending on how much of the receiver one is trying to simulate, an advanced package should simulate both true range and pseudo-range as defined by ICD-GPS-200 (reference 1, also see references 3 and 5). This additional term goes by the name of earth rotation or *light speed iteration* term. The earth rotation term, used in reference 3 page 492, refers to the movement of the satellite

ECEF frame during the transit time. The light speed iteration term gets its name from an iteration algorithm found in GPS RF simulators used to simultaneously solve for satellite movement and signal transport time.

The next sub-categories tally up whether the software packages calculate *Doppler (velocity)*, acceleration, and jerk along the Line of Sight (LOS). The Doppler can be used for the point velocity fix, and Doppler, acceleration and jerk can be used for calculating the amount of dynamics driving the various tracking loops. A "y" means the package calculates theses terms, a "wd" indicates that the software will force the range and clock errors to have the appropriate integral relationships. The next sub-category indicates whether the package calculates *carrier phase* data measurements. A "y" indicates that the package does, and a "well-done" indicates that the package has a provision for keeping track of the whole number of carrier phase cycles, fractional cycles, and has separate book-keeping for cycle jumps that are to occur at user specified times. Simulated SA Dither and Eps dither were given "y" scores if the package supplied both functions, and a well-done was given if explicit references were supplied indicating how the models were derived and their limits. The next two sub-categories cover *ionosphere* and *troposphere* terms. A "y" indicates that troposphere and Klobuchar ionosphere models (references 1-2) are implemented for land-based geometry and the carrier and pseudo-range shift in equal and opposite direction for the ionosphere term. A "well-done" is given if the troposphere and ionosphere models are extended for space based geometry. This typically requires a total electron content (or ionosphere shell model) and additional numerical cut-offs for the troposphere term. A "y" in the *multi-path* category indicates the package can do at least one type of multi-path model, and a "well-done" is given for packages that can do several types of models. A "y" in the scalar local area DGPS (*LADGPS*) sub-category indicates that the package can generate differential corrections. A "wd" indicates that several of the standard types of RTCM 104 message contents with latency can be created. {A "y" in the wide area DGPS (*WADGPS*) indicates that the software can generate vector corrections gathered from a grid of references. A "wd" indicates that several WADGPS grids can be simultaneously processed.} The single and double difference carrier phase data *(single-diff CDGPS and double-diff CDGPS*) rows will have a "y" entry of the package can generate phase data to meaningfully drive RTK (real-time kinematic) GPS navigation algorithms. Chapter 1 of Vol II, reference 2 page 29 and reference 3 page 464 basically define what is needed. {The *attitude fix* sub-category indicates whether the package can be used to create attitude data for testing an attitude algorithm. Our current belief is that you need to simulate antenna line biases in order to fully stress an attitude algorithm. A "y" in the *CNo* category indicates that the package will use range and a receiver antenna gain pattern to calculate the carrier strength arriving at the element. A well-done indicates that antenna arrays are also modeled. The *phase wrap-up* sub-category gets a "y" if vehicle rotation will induce carrier phase wrap-up based on ideal circular polarization models (references 8-9). A well-done is assigned if ellipticity is handled. The *L2* sub-category is scored "y" if you can get both L1 and L2 versions of the measurements. A well-done is given if you can model Rayleigh fading on L1 and L2, both flat and frequency selective, based on scintillation indices.} A "y" in the last category indicates whether *GLONASS* data is generated, and a "wd" if it can be correctly integrated with GPS data.

{ *RF Simulator, Plite (pseudo-satellite), and Jamming Tools*: None of the vendors currently support these areas, so we consider these to be potential business opportunities in the form of add-on options. Simulator utilities would provide methods for converting between sub-frame data-bits and engineering units. Plite tools would include utilities for assessing interference levels and navigation tools that accounted for the ranges being much closer so that $1/R^2$ terms are needed in the filtering equations (GSO Gaussian 2^{nd} order filters). Jamming is the last add-on toolbox we could think of and beyond the scope of this review. }

Table 4.2 GPS measurement selection, navigation accuracy, and algorithm development – Problem 2

Measurement Selection Tools: A "y" indicates that a minimum GDOP criteria can be used to select 4 SVs out of N SVs. A "wd" indicates whether PDOP and other criteria can be used. {Weighted DOP refers to algorithms that allow you to factor in the amount of measurement noise and have similar criteria as previously defined. A "y" in the robust DOP category indicates the package can select the best number of SVs > 4 such that the loss of an extra SV does not drastically alter DOP. A well done is given if the criteria can be changed from GDOP or PDOP.}

Navigation Fix Tools: A "y" in the first sub-category indicates that a point position & time fix can be calculated. A "wd" indicates that the package does something intelligent when 3 SVs are present, (such as

either an altitude or clock hold, or an option to select either) and also when less than 3 SVs are present (such as output of a bad-fix or "gap" status flag). The point velocity fix sub-category has similar scoring rules but the outputs are now velocity and clock drift solutions. The *LADGPS* sub-category has a "y" if the package can do the DGPS fix, and a "wd" if it can handle latency and other message types. {The vector *WADGPS* has similar scoring rules.} The *carrier phase smoothing* sub-category has a "y" if the package can smooth the pseudo range data with carrier data, and a "wd" if it can then use the smooth data in some other fix routine (reference 4 page 443). Supplying an add-on package of advanced navigation algorithms could be a business opportunity, and the following are suggested scorings. A "y" in the *single or double difference* phase fix categories means that the package supplied some type of kinematic (static or real-time) navigation algorithms that work with single and double difference phase data. A "wd" means that an entire system, including initialization calculations of the ambiguities and line bias terms, and real-time (moving base-lines) is provided. {The attitude fix is given a "y" score if a working attitude fix is provided, and a "wd" if outages and other gaps are handled or at least flagged.} The *PVT Kalman Filter* fix is given a "y" score if an entire PVT filter is supplied that calculates fixes (reference 4 page 440). A "wd" is given if the filter is mechanized to accept one measurement at a time so that it performs optimally if less than 4 SVs are present. {A Kalman filter that accepts pseudo-range, Doppler, and carrier phase (*carrier phase KF*) measurements with a PVT model to calculate both position and velocity is given a "y" if present, and a "wd" if it performs optimally with less than 4 SVs. The last sub-category will have a "y" if a *Kalman Filter and sensors*, such as Baro or INS, is provided in working form. A "wd" is given if the filter can handle less than 4 SVs or loss of data from the external sensor (data-gap). In all of the "wd" categories with Kalman Filters, we expect that all units are explicitly defined along with some suggested parameter tuning values.}

Table 4.3 Fault monitoring – Problem 3

Post Fix Tools: The first sub-category is given a "y" if a point *RAIM* algorithm is present that at least computes some type of parity vector. A "wd" is given if it geometry and threshold routines are present that can isolate and detect errors (with enough redundant SVs) as well as alert the user to bad geometry. The second sub-category gets a "y" if the *WAAS system coverage* areas can be plotted. A "wd" is scored if the graphics can be over laid on a map. The third sub-category, *CEP*, has a "y" if the toolbox has the functions for computing and converting between drms, 2-drms, CEP, and other typical factors. A "wd" is given if all the various 2D and 3D conversions are present.

Table 4.4 Reading recorded data – Problem 4

Data Interchange Tools: A "y" in the *NMEA* box means that NMEA data can be parsed into arrays of numbers. A "wd" means that gaps, and synchronization of different data-set streams has been implemented (a non-trivial problem). { A "y" in the *RINEX* sub-category means that RINEX data can be processed, and a "wd" means that different RINEX sets can be synchronized in time for comparison purposes. The other category is scored "y" if you can purchase add-on toolboxes for reading vendor specific binary data sets.}

Table 4.5 Total GPS scenario simulation – Problem 5

Receiver Simulation Tools: This entire sub-category is an on-going research area, but one package tackled it so it is included here. {The first sub-category is checked if the *rule-of-thumb* loss of lock equations in reference 5 chapter 5 are implemented. These equations predict when the various tracking loops lose lock based on the received CNo ratio, LOS dynamic acceleration and jerk levels, and the loop orders and bandwidths. A "wd" score is given if the mean acquisition time equations are evaluated to estimate the time to regain lock. The second sub-category, *linear 2KHz integrate and dump base-band correlator model*, is checked if the model in reference 6 is implemented. A well done score is given if various types of Jammers are implemented by correctly calculating how the CA or P code re-spreads them. The next sub-category, *analytical quantizer and AGC*, is scored with a "y" if analytical models accounting for the adaptive quantizers and AGC are appended to the above models. A "wd" is given if both colored noise and pulse jamming is handled.} The *exact CA* I and Q model is scored "y" if 4 MHz sample rates and the A/D quantizer are fully modeled. A "wd" is given if all of the DSP operations and quanitzation issues are truly modeled. {The same logic is used for a *exact P* code DSP chip except that 40 MHz sampling is required. 4 and 40 MHz execution models are excruciating slow, so it is handy to have the 2 KHz approximate models to get some baseline results. } A "y" in the tracking loop sub-sub-categories indicates

whether you get Delay Lock Loop (*DLL*), Phase Lock Loop (*PLL*), Frequency Locked Loop (*FLL*), *SNR* or CNo algorithms and *Lock detectors* given in reference 5 chapter 5. A "wd" is given if you can select different type of error detectors as specified in reference 5 chapter 5. A "y" in the *bit sync* and *frame sync* indicates you get at least one type of algorithm, a "wd" indicates that you get several to choose from. To get a "y" in the *variable integrate and dump (I/D)* sub-category, you can jump to a new integrate and dump value in the middle of the run. Typical options are 1,2,4,5,10 and 20 msecs with additional post accumulations after the non-linear DLL, PLL or FLL detectors are formed. A "wd" is given if the user is given tools to manipulate these options. A "y" in the tracking *moding* is given if the system can make a transition or narrow a loop bandwidth, and a "wd" is given if you get the lock detectors and SNR meters to drive the decision making. A "y" in the *search* sub-category means that you can start the tracking loop simulation out of lock and simulate search and acquisition. A "wd" means that you get more than one strategy to try. If the simulation is written so that you can automatically create *n tracking* channels, a "y" is scored here. A "wd" indicates that it is easy to do, and moreover each channel can have different parameters. There are a few miscellaneous receiver signal processing functions that at least two vendors supported. The *generate CA* sub-category is scored "y" if you can generate any of the 32 CA Gold-Codes, and a "wd" is given if you can generate all 1025 possible Gold codes. The next sub-category is for generating the *CA correlation* function. A "y" is given if you can generate the correlation function at zero Doppler at full chip spacing, and a "wd" is given if you can generate the cross-correlation, auto-correlation, and correlation with noise/jamming data at any Doppler shift (reference 2 Vol. II page 70). The last sub-category gets a "y" score if you generate the *ROC* (receiver operating curve) that characterizes the probability of acquisition as a function of the CNo for given false alarm rates. A "wd" is given if you can predict the mean acquisition time as a function of Doppler and code uncertainty intervals, dynamics, and CNo for two popular search strategies (reference 5 page 203).

Table 4.6 Presentation quality graphics – Problem 6

Presentation Graphics: A "y" in the first sub-category, *basic*, means that you get sky plots of azimuth and elevation in local level, bar charts of number of SVs, and DOP plots. A "wd" is given if you can generate the azimuth and elevation plots in antenna frames and visualize the 3D geometry of the line of sight vectors and when they are blocked by earth and body entities. The *Mercator* sub-category is scored with a "y" if satellite locations and user locations can be over-laded on a mercator map. A well done is given if the square aspect ratio can be controlled. A "y" in the *quality* sub-category indicates that you can get presentation quality plots and movies out, and a "wd" is given if hard-copy control actually works in black and white and color. A "y" in the *gap* sub-category means that there is intelligent handling of data gaps, and a "wd" is given if it is efficient in terms of post script plotting resources. {A "y" in the *chunking* category is given if you can scroll through portions of huge data-sets, and a "wd" if it can be done efficiently.} A "y" in the *interactive scaling* sub-category is given if you can zoom in and out on the scales of a plot, and a "wd" if you can select options to trim the first n largest and smallest points out of the plot.

Scoring Rule References

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3) Strang and Borre, "Linear Algebra, Geodsey and GPS", 1997 Wellesely-Cambridge Press and the web sites: www-math.mit.edu/~gs, www.i4.auc.dk/borre, and www.i4.auc.dk/borre/matlab

4) Brown and Hwang, "Introduction to Random Signals and Applied Kalman Filtering with MATLAB Exercises and Solutions", Third Edition, 1997, John Wiley and Sons

5) Kaplan et-al, "Understanding GPS Principles and Applications", Artech House, 1996

6) Ward, P., "Using a GPS Receiver Monte-Carlo Simulator to Predict RF Inteference Performance", ION 97, page 1473, Kansas City Mo.

7) Satellite Simulator Control Working Group (SSCWG), “GPS Receiver Boundary Rollover Test Plan”, see web site http://www.laafb.af.mil/SMC/CZ/homepage/index.html.

8) Tetewsky A. and Mullen F, “Effects of Platform Rotation on GPS with Implications for Simulators”, GPS-ION meeting, Sept 1996 Kansas City Mo.

9) Mullen F. and Tetewsky A. “Rotating Lever Arm Effects on GPS Carrier”, 23rd Joint Services Data Exchange for Guidance, Navigation, and Control, Orlando Florida 19 Nov 1996.

10) Musick, S. H., “Users Guide for Flight Profile Generator (PROFGEN)”, Sept 1997, 937-255-1115 ex 4292 Musicksh@SENSORS.WPAFB.AF.MIL