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STAR SELECTION ALGORITHM REQUIREMENTS

AXAF SCIENCE CENTER

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STAR SELECTION ALGORITHM REQUIREMENTS

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Preface

This document constitutes the requirements specification for the AXAF Star Selection Algorithm, and is submitted as an update to and replacement for the preliminary version dated 8 Dec 1994. This specification is as complete as current knowledge of the AXAF hardware characteristics permits, and is provided for use in preparation for AXAF program CDRs that are scheduled to take place between July 1995 and Feb 1996. Further revisions to this specification are anticipated, as additional information and analysis results emerge.

Contents

1 Introduction

1.1 Objectives

This document specifies the functional requirements for the AXAF star selection algorithm (SSA) that is to be implemented in the OCC for use in the mission planning activity for selecting acquisition stars and guide/aspect stars from the AXAF star catalog for each AXAF science observation. The purpose of this document is to provide the requirements basis for star selection software design by the OCC OFLS development team. This specification defines the algorithm for the star selection process, together with an operational sequence diagram, a textual description of each step in the sequence, and a definition of inputs and outputs for each step. Because of algorithm dependencies on certain characteristics of the aspect camera assembly (ACA), other elements of the AXAF pointing control and aspect determination (PCAD) subsystem, and the information content in the final star catalog (scheduled for delivery in 1997), none of which are yet available, updates to the functional requirements specification are anticipated. To the extent possible we have attempted to anticipate possible changes by defining variable parameters in the ODB, and allowing for changes in the AGASC. We plan to review this specification as more information becomes available on the ACA, the PCAD and the star catalog and to issue revisions as necessary.

1.2 Scope

The scope of this document includes the complete OCC processing required to identify and select stars from the AXAF star catalog which meet the requirements of acquisition stars, guide stars, and aspect stars. Acquisition stars support real-time attitude updating of the PCAD after an extended spacecraft slew to a new pointing direction. Requirements for selection of these stars have been defined by TRW, and have been integrated into the star selection algorithm by the ASC. Guide stars support real-time attitude holding by the PCAD during an observation. Aspect stars support precision post-facto attitude history determination by the ASC as part of the observation data ground processing.

It has been determined by TRW that a set of stars that meet aspect-star criteria will also satisfy guide-star criteria, so that only a single set of (nominally) five stars need be selected by the algorithm to serve both functions. It has further been determined by TRW that, at least for some observations, acquisition stars that are distinct from the guide/aspect stars will be required to assure reliable real-time attitude updating within the PCAD after an extended slew.

The star selection algorithm includes identification of candidate stars in the ACA field of view during an observation pointing together with potential column-spoiler stars, selection of candidate star sets from this group that meet specified criteria, and evaluation of candidate star sets against performance-related criteria. The algorithm selects acceptable sets of guide/aspect stars first, and then applies acquisition-star selection criteria to determine whether a single set of five stars can be identified which satisfies both functions. Contingency actions are specified which define further algorithmic functions, in the event that difficulties occur in selecting either guide/aspect stars or acquisition stars.

2 Applicable Documents

1. AMO-2000, AXAF Operations Ground System Requirements, 17 June 1994
2. AMO-2050, OCC/ASC Interface Control Document, 15 June 1995 (to be published)
3. SAO Internal Memo, "The HEAO-B Star Trackers", Steve Murray and Leon VanSpeybrock, 1973
4. AXAF Star Catalog (preliminary), June 1994
5. TRW DR OP19, Operations Data Base User Guide, 15 May 1995
6. ASC TIM, Star Colors vs. Magnitude Range, 1 Feb 1995, M. Garcia
7. ASC TIM, Star Colors vs. Luminosity on Galactic Plane, 14 Feb 1995, M. Garcia
8. ASC TIM, Test Runs of GASSA v1.0, 24 Mar 1995, M. Garcia
9. ASC TIM, Tests of Acquisition Star Algorithm, v2.1, 3 May 1995, M. Garcia

3 General Description

3.1 Assumptions

The algorithm described in this document reflects the following assumptions:

1. The algorithm must be suitable for operational use in the OCC environment; in particular, it must be capable of automatic execution, without operator intervention

2. The algorithm must obtain its input data from standard sources, consisting of specific data elements in the Operations Data Base (ODB), without requiring FOT interpretation of unstructured scientific information to handle contingencies, or ad hoc requests to the ASC for supplemental input. (The ODB data elements that support star selection with the algorithm are: the AXAF Star Catalog, the Star Selection Algorithm (SSA) Parameters (see Appendix D), the Observation Request (OR) List, and the AXAF Characteristics (TBR).)

3. The algorithm must converge on an acceptable set of stars most of the time, with failure of the algorithm an unusual occurrence.

4. The algorithm must allow for occasional specification of one or more aspect or acquisition stars by the ASC, as part of the Observation Request (OR); *e.g.*, when it is scientifically desirable to obtain the optical signature of a target in the ACA field of view, as part of the observation data.

5. The algorithm must allow for complete specification of all of the aspect or acquisition stars by the ASC as part of the OR, in unusual situations where either the scientific objectives of the observation require selection against more-stringent or otherwise different selection criteria than are used by the OCC algorithm, or when it is determined by either the ASC or the OCC that the algorithm does not produce scientifically adequate sets of stars (*e.g.*, near very dense star regions or regions with variable or diffuse background.)

6. The stars selected by the algorithm will be available to the ASC for examination for compatibility with the scientific objectives of the observation, as part of the mission schedule review and concurrence process. A possible but infrequent outcome of the review process may be specification of a different set of stars.

7. There will be a set of SSA parameters which the algorithm will obtain as input from the ODB. These parameters will nominally be fixed, but easy to update as needed as a result of ASC trends analysis.

3.2 Operational Sequence

An overview of the star selection process is shown in Figure 1. This overview shows the interaction between the guide/aspect star selection (GASSA) and the acquisition star selection (ASSA). The output of the guide/aspect selection is an ordered list of star sets. This list is ordered by FOM, so that the best set of stars is listed first. Star sets are taken from the top of this list, and each is tested by the ASSA (every acceptable set candidate guide/aspect stars is tested) in order to see if it can also be used for acquisition stars. The algorithm ends as soon as a set of stars is found that serves both purposes. If none of the acceptable sets of guide stars can also serve as acquisition stars, then the acquisition algorithm attempts to find a different set of stars from the AGASC which can be used for acquisition.

The guide/aspect star selection algorithm is described in Figures 2,3 and 4, in the form of an operations sequence diagram. Data inputs to each step in the sequence are defined by the arrows at the left of the corresponding function. The individual steps in the sequence are as follows:

1. Using the pointing angles in celestial coordinates (RA, DEC) specified in the OR for the subject pointing, together with the Search Radius specified in the ODB, determine the nominal Star Search Region in celestial coordinates (the coordinates of the star catalog).

2. Identify stars from the star catalog that lie within the Star Search Region.

3. Identify stars within the Star Search Region whose images will reliably lie on the ACA detector (CCD array), considering the geometry of the observation and the spacecraft pointing uncertainties. (These are the initial candidates for both aspect and acquisition stars.) Retain other stars within the Star Search Region for later evaluation as potential column spoiler stars.

4. Identify, and eliminate from the list of candidates, stars whose expected brightness as seen by the ACA detector is below a lower limit or above an upper limit. The expected brightness is either specified in the Star Catalog, or is determined by the brightnesses listed in the star catalog for one or more colors along with conversion factors that relate these to the expected brightness as seen by the ACA detector. The ACA apparent magnitude and the conversion factors are included as SSA Parameters in the ODB. Periodic updates will be provided to the OCC by the ASC as part of the trends analysis, as the ACA detector properties change.

   > Note: Eliminating insufficiently bright stars is necessary to achieve sufficiently accurate guide star centroids. Both internal detector noise and sensitivity of the ACA detectors to distortion of the point spread function (PSF) from other nearby stars render faint stars unacceptable. Eliminating stars that are overly bright is aimed at reducing detector saturation.

   This brightness screening is bypassed for stars specified for this observation by the ASC in the OR, or as part of the MS concurrence process. Such stars that are used that are outside the magnitude default limits should be prominently flagged in the MS.

5. Identify, and eliminate from the list of candidates, stars which fail to meet criteria associated with freedom of imaging interference from nearby stars and FID lights, or proximity to dead spots in the ACA, or whose Quality Code (QC) as listed in the star catalog does not fall within a specified range. [The QC characterizes the accuracy with which the star image centroid position can be determined.]

6. Form sets of five stars, consisting of aspect stars specified by the ASC in the OR plus additional stars from the list of screened candidates, and calculate a figure-of-merit (FOM) for each set. Check stars specified by the ASC in the OR for compatibility with these spatial filtering

criteria (which are roll-angle sensitive, and therefore cannot be checked a priori by the ASC). If any ASC-specified star fails this filtering check, delete the star from the ASC-specified list, report the failure, and proceed. Compare the FOM to a specified selection criterion (e.g., lowest achievable FOM or FOM below a threshold), and continue until either the selection criterion has been satisfied or it is determined that there is no set of stars from among the screened candidates which satisfies the criterion. Order the sets of stars which have acceptable FOMs according to increasing FOM. For each set compute three Group Quality Codes (GQC) which are the sums of the three QC values for the individual stars as listed in the Star Catalog.

7. If no set of stars is found that satisfies the (default) specified selection criterion, an expanded search is conducted, based on modified viewing geometry (roll angle, observation schedule), selection of an alternative set of FID lights, and allowing stars with higher QC. If the expanded search still does not satisfy the selection criterion, the best set of aspect stars is selected and a flag is set in the Mission Schedule to indicate this.

8. The selected acquisition and aspect stars are provided by the OFLS in the Mission Schedule, for review by the ASC against the science objectives of the observation as part of the Mission Schedule review. Under exceptional circumstances, based on the science objectives of the observation, the ASC might request a change in the selection of acquisition or aspect stars as part of the MS concurrence process.

Selection of acquisition stars is based on the guide star algorithm, with a few differences. The "filtering" of stars proceeds identically, but there is an additional positional error term (due to the slew between targets) which must be considered when searching for column spoilers. The AGASC quality codes for acquisition stars take this larger slew error into account, and are therefore different than the quality codes for guide/aspect stars. There is no need to determine a FOM for acquisition stars. Instead, the stars are ordered by magnitude (brightest stars first) and star sets are chosen from this ordered list. Therefore acquisition stars will on average be brighter than guide/aspect stars (if the sets are different).

4 Functional Requirements, Guide/Aspect Stars

This section defines the functional requirements for the guide star selection algorithm. The requirements are organized to follow the flow chart presented in Figure A.

This section specifies functional requirements only. There are no performance or design requirements on the SSA algorithm that are governed by this specification.

4.1 General Requirements

1. If the OR (or MS concurrence process) specifies all stars, then bypass brightness checks (4.5) and QC checks (4.6.1) but check to see that the stars fall on the ACA (4.4.1) and check for column spoilers (4.6.4) and check the ACA bad pixel map (4.6.3). Then bypass FOM-based checks (4.7) and contingency checks (4.9).

2. If the OR (or MS concurrence process) specifies one or more stars,then bypass brightness checks (4.5) and QC checks (4.6.1) but check to see that the stars fall on the ACA (4.4.1) and check for column spoilers (4.6.4) and check the ACA bad pixel map (4.6.3). Then proceed to optimize the FOM (4.7), given the constrained set.

3. When the OR specifies a complete set of fiducial lights for an observation, the software shall select those fiducial lights, irrespective of the results of applying the algorithm specified in the following sections.

4.2 Determine Nominal Field of View (Flow Chart Block 1)

The software shall determine a Star Search Region (SSR), in celestial coordinates (J2000 coordinates, as used in the Star Catalog), based on the following:

1. Right Ascension (RA) and Declination (DEC) for the specific pointing, as specified in the relevant Observation Request (OR)

2. A Search Radius, as specified in the SSA Parameters data element of the Operations Data Base (ODB).

The SSR is expressed as a center point and an angular radius, and defines the spatial region from which to select candidate acquisition/aspect stars, and to identify potential interfering ("column spoiler") stars, from the star catalog. The SSR is larger than the ACA field of view, and includes margins for pointing offsets from the specified pointing coordinates and a roll angle that is (typically) determined during the mission scheduling process and is unknown prior to this time.

The pointing offsets include contributions from dither, slew errors, attitude hold error, and boresight offset.

4.3 Determine Stars in Field of View (Flow Chart Block 2)

The software shall identify all stars whose celestial coordinates are within the spatial bounds defined by the SSR, using star identifications and star positions listed in the AXAF Star Catalog data element of the ODB.

4.4 Select Candidate Guide/Aspect Stars (Flow Chart Block 3)

Stars whose images will reliably fall on the ACA detector, considering pointing errors and other factors, are retained for consideration as guide/aspect stars. All others within the SSR are eliminated from further consideration except those that might be potential column spoilers (see Section 4.6). These stars are stars which are sufficiently bright that may fall on the ACA CCD chip during the observation. To determine the set of stars that may fall on the chip, it is necessary to project the CCD on the SSR and consider the maximum excursion of the chip location taking; into account attitude hold error and programmed dither.

4.4.1 Determine Spatial Subregion of SSR That Is Subtended By the ACA Detector

The software shall calculate the spatial bounds of the subregion of the SSR which will be imaged on the ACA detector with high confidence, considering expected pointing errors (pitch, yaw)and pointing angle (roll) variations. Calculation of the spatial bounds of the subregion will be based on the following parameters:

1. The reference aperture of the ACA detector, as specified in the SSA Parameters data element of the ODB. The reference aperture is specified as a rectangular array of ACA pixels, plus a pixel size (arcsec).

2. The roll angle for the observation. The roll angle is determined initially by the OFLS, using mechanisms not governed by this specification, unless specified in the OR. (The roll angle may be varied as part of this algorithm, under conditions described in Section 4.9)

3. The maximum pointing error that can occur during attitude hold, as specified in the SSA Parameters data element of the ODB.

4. The dither amplitude for the observation. The maximum dither amplitude that can occur is specified in the SSA Parameters data element of the ODB. The OR specifies whether dithering is to be implemented for the observation, and the amplitude of the dither.

5. The HRMA boresight correction, which defines the angular separation of the HRMA and ACA boresight axes, and is provided in the ODB.

The calculation will be carried out by using the roll angle to orient the reference aperture on the sky, reducing both rectangular dimensions of the resulting subregion by the sum of the maximum pointing error and the dither amplitude, and using the boresight correction to shift the center of the reference aperture away from the specified pointing RA and DEC.

4.4.2 Identify Spatially-Filtered Candidate Stars

The software shall identify the stars within the SSR whose images will reliably fall on the ACA detector, by comparing each stellar position with the bounds of the spatial subregion defined in 4.4.1, and selecting those stars whose positions fall within these spatial bounds.

4.4.3 Retain IDs of Potential Column Spoiler Stars

The software shall retain, for examination as potential column spoilers, the identities of all stars within the SSR whose positions lie outside the bounds of the spatial subregion defined in 4.4.1 .

4.4.4 Check FIDs for Stellar Column Spoilers

If a FID light is readout through a bright star, then the position of the FID light may be artificially distorted. Check to see if this will occur, and if so, attempt to avoid this by changing the roll angle as outlined in Section 4.9.1. If changing the roll angle does not avoid the condition, attempt the alternate FID light set as in Section 4.9.2. If this does not alleviate the condition, select the default set of FIDs and default roll, continue with the algorithm, and prominently indicate the FID and associated column spoiler star in the MS. In order to be a potential column spoiler the star must be "col_mag_diff_limit_a" brighter than the FID light, and must be within "col_spoil_col_limit" columns of the FID light. The apparent magnitude of the FIDs is listed in the SSAPE/ODB as "fid_aca_mag".

4.5 Select Stars Based on Brightness (Flow Chart Block 4)

Identify stars from the list of candidate guide/aspect stars that may be too dim or too bright to use.

4.5.1 Get Instrumental Magnitudes

The software shall determine the instrumental magnitude of each star in the list. The instrumental magnitude is the stellar brightness as measured by the ACA. It is determined from the AGASC in the following way:

- if the "star_mag_conv_flag" (in the SSAPE/ODB[1]) has been set to 0, then the software will read the MAG_I directly from the AGASC.
- if the "star_mag_conv_flag" (in the SSAPE/ODB) has been set to 1, then the software shall compute MAG_I from the magnitudes in various colors as listed in the AGASC. The polynomial formula for computing MAG_I is described below.

The coefficients of this polynomial are SSAPE/ODB input parameters with initial default values, the variables in the polynomial are the magnitude and colors in the AGASC, V1.1, ie, MAG, C1, C2, C3. The coefficients will vary with time as the star camera ages (periodic updates will be provided by the ASC as part of the trends analysis). There will be a different set of coefficients for each of the ($\sim$ 10) "MAG_BAND" codes in the AGASC. For a single MAG_BAND, for example:

$$\begin{aligned} MAG\_I &= aca\_mag\_00 + aca\_mag\_01(MAG\_I) + \\ &\quad aca\_mag\_01\_c1(C1) + aca\_mag\_01\_c2(C2) + aca\_mag\_01\_c3(C3) + \\ &\quad aca\_mag\_01\_c12(C1 - C2) + aca\_mag\_01\_c23(C2 - C3) + aca\_mag\_01\_c13(C1 - C3) + \\ &\quad aca\_mag\_02\_c12(C1 - C2)^2 + aca\_mag\_02\_c23(C2 - C3)^2 + aca\_mag\_02\_c13(C1 - C3)^2 \end{aligned}$$

[1]SSA Parameters data element of the Operations Data Base

The coefficients aca_mag_00, aca_mag_01, aca_mag_01_c1, etc., will be taken from the SSAPE/ODB and will be provided by the ASC.

4.5.2 Filter Faint Stars

The software shall filter all stars dimmer than the instrumental magnitude "g_max_mag" (which is specified in the SSA parameter element of the ODB). "Filter" means to flag the star as being unacceptable as a potential guide/aspect star. Stars that have been specified by the ASC for inclusion in the guide/aspect star set should not fail this filter no matter what their magnitudes (*i.e.*, this test should be bypassed for stars specified in the OR list or in the MS concurrence process by the ASC).

4.5.3 Filter Bright Stars

The software shall filter all stars brighter than the instrumental magnitude "g_min_mag" (which is specified in the SSA parameter element of the ODB). Stars that have been specified by the ASC for inclusion in the guide/aspect star set should not fail this filter no matter what their magnitudes (*i.e.*, this test should be bypassed for stars specified in the OR list or in the MS concurrence process by the ASC).

4.6 Apply Spatial Filters on Stars (Flow Chart Block 5)

Identify all stars from the list of candidate stars that pass all of the tests defined in this section. We refer to this set of stars as the "filtered star list" below. Some of these tests check the value of the Quality Codes (QC) in the AGASC (V1.1), in order to determine if they are within the ranges allowed or are suitably small (see below).

4.6.1 Filter on QC

The software shall identify the candidate stars for which the corresponding QCs listed in the AGASC fall between the limits specified in the SSA parameter fields of the ODB. As defined by the ASC, lower values of the QCs are "better", and therefore only stars which have QCs equal to the lower bound will be accepted for the first (and most likely only) pass through the SSA. Possible additional passes, and treatment of the QCs, are described in section 4.9.3. The three QCs listed in the AGASC (V1.1) are "ASPQ1", "ASPQ2", and "ASPQ3". The low and high bounds of the acceptable ranges are the ODB elements "guide_c1_code_min", "guide_c1_code_max", "guide_c2_code_min", "guide_c2_code_max", "guide_c3_code_min", "guide_c3_code_max".

The factors that go into the computation of the QCs are irrelevant to the OCC implementation of the SSA. For information purposes, however, they include such things as the presence of nearby stars ("spoilers" that can make the centroiding of a stellar position difficult), large positional uncertainties, known binary nature, known large proper motions, known excessive variability, and other factors.

4.6.2 Filter on FID Spoilers

The software shall identify (and flag for exclusion) stars that may be too close to the fiducial lights. "Too close" is defined by the SSAPE/ODB parameter "fid_spoil_region". Note that because shifts in the pointing direction cause the stars to move across the ACA while the FIDS do not, the allowable errors due to attitude hold ("max_point_error" parameter in SSAPE/ODB) and dither ("max_dither" parameter in SSAPE/ODB) must also be included in the evaluation of proximity of the star with respect to the FIDs.

4.6.3 Filter on ACA Bad Pixel Map

The software shall (and flag for exclusion) identify stars that may fall in bad regions of ACA CCD. This region is defined in the SSA parameter field of the ODB as the entry called "ACA detector bad-region map". As above, note that attitude hole error and dither must be considered in defining the size of the regions.

4.6.4 Filter Column Spoiler

The software shall identify (and flag for exclusion) stars that may have CCD "column spoilers" (*i.e.*, if a candidate star is read out through a column in which another bright star or FID light lies, it will be "spoiled" by the star or FID light). A star is considered bright, in this context, if its magnitude is "col_mag_diff_limit_g" (SSAPE/ODB) smaller than the star being considered. FIDS are always considered possible column spoilers. Stars (and FIDS) are considered to be in the same column, in this context, if they are readout within "col_spoil_col_limit" (from the SSAPE/ODB) columns.

4.6.5 Collect Filtered Star List

The stars that have passed all of the above tests will then be suitable candidates for guide/aspect stars, and form the "filtered star list". If there are more than "max_filtered_list_len" (SSAPE/ODB) stars in this list, removed the fainter ones in order to get the list down to this size. From this list, a set of stars (five, unless otherwise specified in the OR) will be chosen as candidate guide/aspect stars. The technique for selecting these sets of stars is described in the following sections.

4.7 Test for Performance Adequacy (Flow Chart Block 6)

Calculate a figure of merit (FOM), related to the predicted uncertainty in the precision aspect solution. Decide when a set of stars (5 typically) has been found that provides satisfactory performance as determined by the figure of merit. Determine three Group Quality Codes, which are the sum of the individual aspect QCs (ASPQ1, etc.) for each of the stars in each set. Sets of stars should have GQCs in an allowed range (as well as acceptably low FOMs) in order to be considered as acceptable guide/aspect star groups.

4.7.1 Position Uncertainty, Single Star

For each star in the list of accepted stars, the software shall compute the predicted uncertainty in the centroid of the stars on the ACA. This uncertainty is a function of the instrumental magnitude of the star (brighter stars provide more precise centroids) and systematic errors. The formula for the uncertainty (σ_i) in the centroid of an individual star is given and discussed in Appendix A.

4.7.2 Compute Figure of Merit

The software shall compute the FOM for all sets of N (5, unless otherwise specified in the OR) stars drawn from the filtered star list. Note that for every set of N stars, there is a separate FOM calculation. The FOM calculation is given in Appendix C. It shall flag those sets of stars that have an FOM lower than the maximum specified in the SSAPE/ODB ("max_acceptable_fom").

4.7.3 Compute Group Quality Codes

For the collection of star sets with acceptable FOMs, the software shall compute three Group Quality Codes (GQC). The GQC are the sums of the individual three QCs for the individual stars in the set.

4.7.4 Suspend FOM and GQC Checks for OR Specified Stars

The software shall permit constraints on the selection of stars; for example, the OR (or MS concurrence process) may pre-select one or more stars to be used as guide/aspect stars (such as the X-ray target). If all the guide/aspect stars are pre-selected, the FOM and GQC shall be computed for such sets, but no FOM/QC acceptability criteria will be applied. Such stars that are outside the normal brightness limits will be prominently flagged in the MS.

4.7.5 Compute FOM, GQC if Less Than N Stars

The software shall compute an FOM and GQC if fewer than N stars are found in the filtered star list determined in Section 4.6.5. If at least one set of stars meeting the FOM and GQC criteria are found, then the algorithm proceeds to Section 4.10, and sets an aspect quality indicator in the MS to indicate GASSA goals have been met. Otherwise it proceeds to Section 4.9 (Flow Chart Block 7).

4.8 Collect Ordered List

The sets of stars having acceptable FOMs and GQC shall be ordered by FOM (smallest first). The length of the list shall be limited to "fom_list_length" (SSAPE/ODB) by dropping those sets with the larger FOMs.

4.9 Depart from Nominal Observation Parameters to Find Acceptable Set of Guide/Aspect Stars (Flow Chart Block 7)

This section specifies how the algorithm should respond if it doesn't find a set of N stars (where N= 5 or OR specified number) that satisfies the FOM/GQC criterion (Sections 4.6 and 4.7). The software is to attempt each of the fixes below in turn. If one of the fixes works, then the search should terminate, and the algorithm proceeds.

4.9.1 Try Off Nominal Roll

If the FOM/GQC are unsuitable, then the software should make small changes in the nominal roll angle (± 1 degree, ± 2 degrees, ... up to the nominal roll limit; as determined from the AXAF Characteristics data element in the ODB). If the roll has been specified in the OR, then small changes in the roll up to the delta_roll allowed in the OR may be made. The algorithm then branches back to Section 4.3 (Flow Chart Block 3) and determines a new set of candidate stars and new set of FOMs/GQCs. If this "fix" works, then the new set of stars is returned in the MS, along with an indication in the MS that it was necessary to use an off-nominal roll.

4.9.2 Try Alternate FID Lights

If the "fix" in Section 4.9.1 fails, then the software should try using the alternate FID light set. This should first be attempted at the nominal roll, and then at off-nominal rolls as in 4.9.1. If using the alternate FID light set works, then there should be an indication in the MS that the alternate set was used, and the names (numbers) of the alternate FIDS should be listed in the MS.

4.9.3 Accept Higher QCs

If the alternatives in sections 4.9.1 and 4.9.2 fail to find acceptable FOM/GQC, then the software should branch back to the QC filtering section (4.6.1) and allow stars with the next highest integer value of the ASP-QCs. This should continue until an acceptable set of stars is found, or the maximum allowable value of the ASP-QC is reached ("acq_c1_code_max", in SSAPE/ODB) for each of the three QCs. A non-zero value of the GQC is then reported in the MS. The use of higher QCs should first be attempted at the nominal roll, then at off-nominal roll, then at nominal roll, alternate FID lights, then at off-nominal roll with alternate FID lights.

If no set of stars is found after the extended search process described in Section 4.9 is completed, the MS shall halt further processing of the OR and report the results of Section 4.9 processing in the free-text files of the MS. An aspect quality indicator will also be set in the MS to indicate that the GASSA goals have not been met.

4.10 Report Results (Flow Chart Block 8)

The results of the SSA shall be reported to the ASC in the MS. The report shall include (but need not be limited to)

- A histogram of the FOM for the sets in this final list, and the FOM for the chosen set of guide/aspect stars.
- The characteristics of the selected set of stars, including AGASC identification, RA/DEC, instrumental magnitude, spectral type, and quality code. Stars that have been pre-selected in the OR should be labeled as such. In addition, pre-selected stars that fail the magnitude range and QC checks shall be highlighted in the report.
- If OR selected stars are found to fail spatial filters, it should be reported in the MS which spatial filter was failed by the star.

5 Functional Requirements, Acquisition Stars

This section defines the functional requirements on the acquisition star selection algorithm. The requirements are organized to follow the flow chart presented in Figure A, which is specifically for guide/aspect stars, but also largely applies to acquisition stars.

This section specifies functional requirements only. There are no performance or design requirements on the SSA algorithm that are governed by this specification.

5.1 General Requirements

1. If the OR specifies one or all of the stars, then bypass brightness checks (5.5) and QC checks (5.6.1) but check to see that the stars fall on the ACA (5.4.1) and check for column spoilers (5.6.4) and check the ACA bad pixel map (5.6.3).

2. When the Guide/Aspect Star Selection Algorithm specifies a complete set of trial acquisition stars for an observation, the software shall determine if those stars pass all of the filters outlined below.

3. When the OR specifies a complete set of fiducial lights for an observation, the software shall select those fiducial lights, irrespective of the results of applying the algorithm specified in the following sections.

5.2 Determine Nominal Field of View (Flow Chart Block 1)

The software shall determine a Star Search Region (SSR), in celestial coordinates (J2000 coordinates, as used in the Star Catalog), based on the following:

1. Right Ascension (RA) and Declination (DEC) for the specific pointing, as specified in the relevant Observation Request (OR)

2. A Search Radius, as specified in the SSA Parameters data element of the Operations Data Base (ODB).

The SSR is expressed as a center point and an angular radius, and defines the spatial region from which to select candidate acquisition/aspect stars, and to identify potential interfering ("spoiler") stars, from the star catalog. The SSR is larger than the ACA field of view, and includes margins for pointing offsets from the specified pointing coordinates and a roll angle that is (typically) determined during the mission scheduling process and is unknown prior to this time. The pointing offsets include contributions from programmed dither, mispointing errors after a slew, attitude hold errors, and boresight mis-alignment.

5.3 Determine Stars in Field of View (Flow Chart Block 2)

The software shall identify all stars whose celestial coordinates are within the spatial bounds defined by the SSR, using star identifications and star positions listed in the AXAF Star Catalog data element of the ODB.

5.4 Select Candidate Acquisition Stars (Flow Chart Block 3)

Stars whose images will reliably fall on the ACA detector, considering pointing errors and other factors, are retained for consideration as acquisition stars. All others within the SSR are eliminated from further consideration, but are held for examination in Section 5.6 as potential "column spoilers."

5.4.1 Determine Spatial Subregion of SSR That Is Subtended By the ACA Detector

The software shall calculate the spatial bounds of the subregion of the SSR which will be imaged on the ACA detector with high confidence, considering expected pointing errors (pitch,yaw) and pointing angle (roll) variations. Calculation of the spatial bounds of the subregion will be based on the following parameters:

1. The reference aperture of the ACA detector, as specified in the SSA Parameters data element of the ODB. The reference aperture is specified as a rectangular array of ACA pixels, plus a pixel size (arcsec).

2. The roll angle for the observation. The roll angle is determined initially by the OFLS, using mechanisms not governed by this specification, unless defined in the OR. (The roll angle may be varied as part of this algorithm, under conditions described in Section 5.8.)

3. The maximum pointing error that can occur during attitude hold, as specified in the SSAPE/ODB.

4. The maximum pointing error (radius in arcsec) that can occur after a slew, as specified in the SSA Parameters data element of the ODB. This value increases with the length of the slew. We quantize this error in six steps, using the following prescription

$$
\begin{aligned}
\text{Slew\_Error} &= M_1 \times \Theta_{slew} + \beta_1; \text{ for } \Theta_0 < \Theta_{slew} < \Theta_1 \\
&= M_2 \times \Theta_{slew} + \beta_2; \text{ for } \Theta_1 < \Theta_{slew} < \Theta_2 \\
&= M_3 \times \Theta_{slew} + \beta_3; \text{ for } \Theta_2 < \Theta_{slew} < \Theta_3 \\
&= M_4 \times \Theta_{slew} + \beta_4; \text{ for } \Theta_3 < \Theta_{slew} < \Theta_4 \\
&= M_5 \times \Theta_{slew} + \beta_5; \text{ for } \Theta_4 < \Theta_{slew} < \Theta_5 \\
&= M_6 \times \Theta_{slew} + \beta_6; \text{ for } \Theta_5 < \Theta_{slew} < \Theta_6
\end{aligned}
$$

   where Θ_{slew} is the slew distance (in degrees) computed by the OFLS system, and Θ_x set the applicable ranges in slew angles. Nominal value of the slew error for a 180 degree slew is $133''$, the slew error for smaller slews will be smaller. The values of the parameters above depend on the TBD specifics of the AXAF Gyro set, but will be contained in the SSAPE/ODB.

5. The dither amplitude for the observation. The maximum dither amplitude that can occur is specified in the SSAPE/ODB. The OR specifies whether dithering is to be implemented for the observation, and the amplitude of the dither.

6. The HRMA boresight correction, which defines the angular separation of the HRMA and ACA boresight axes, and is provided in the ODB.

The calculation will be carried out by using the roll angle to orient the reference aperture on the sky, reducing both rectangular dimensions of the resulting subregion by the sum of the maximum pointing error and the dither amplitude, and using the boresight correction to shift the center of the reference aperture away from the specified pointing RA and DEC.

5.4.2 Identify Spatially-Filtered Candidate Stars

As for Guide/Aspect Stars, Section 4.4.2

5.4.3 Retain IDs of Potential Spoiler Stars

As for Guide/Aspect Stars, Section 4.4.3

5.5 Select stars based on brightness (Flow Chart Block 4)

As for Guide/Aspect Stars, Section 4.5

5.5.1 Get Instrumental Magnitudes

As for Guide/Aspect Stars, Section 4.5.1

5.5.2 Exclude Faint Stars

As for Guide/Aspect Stars, Section 4.5.2, except:
Replace "g_max_mag" with "a_max_mag" from the SSAPE/ODB.

5.5.3 Exclude Bright Stars

As for Guide/Aspect Stars, Section 4.5.3, except:
Replace "g_min_mag" with "a_min_mag" from the SSAPE/ODB.

5.5.4 Rank Order by Brightness

Order the list of stars passing the filters by brightness (instrumental magnitude), with the brightest stars first.

5.6 Apply Spatial Filters on Stars (Flow Chart Block 5)

As for Guide/Aspect Stars, Section 4.6.

5.6.1 QC Filters

As for Guide/Aspect Stars, Section 4.6.1, expect:
Replace "ASPQ1", etc., with "ACQQ1, etc., (from the AGASC) and replace "guide_c1_code_min", etc., with "acq_c1_code_min" (from SSAPE/ODB).

5.6.2 Filter FID Spoilers

The software shall identify stars that may be too close to the fiducial lights. "Too close" is defined by the SSAPE/ODB parameter "fid_spoil_region". Note that because changes in the pointing direction cause the stars move across the ACA while the FIDS do not, the allowable errors due to slew, attitude hold, and dither ("max_slew_error", "max_point_error", "max_dither" parameters in SSAPE/ODB) must also be allowed for.

5.6.3 Filter on ACA Bad Pixel Map

The software shall identify stars that may fall in bad regions of ACA CCD. This region is defined in the SSA parameter field of the ODB as the entry called "ACA detector bad-region map". As above, note that slew errors, attitude hold errors, and dither must be allowed for.

5.6.4 Filter Column Spoilers

The software shall identify stars that may have CCD "column spoilers" (*i.e.*, if a candidate star is read out through a column in which another bright star or FID light lies, it will be "spoiled" by the star or FID light). A star is considered bright, in this context, if its magnitude is "col_mag_diff_limit_a" (SSAPE/ODB) smaller than the star being considered. FIDS are always considered possible column spoilers. Stars (and FIDS) are considered to be in the same column, in this context, if they are readout within "col_spoil_col_limit" (SSAPE/ODB) columns.

5.6.5 Collect Filtered Star List

The stars that have passed all of the above tests will then be suitable candidates for acquisition stars, and form the "filtered star list". From this list a set of stars (typically 5, but specified in the OR) will be chosen as candidate acquisition stars. The technique for selecting these sets of stars is described in the following sections.

5.7 Select Brightest Acquisition Stars (Flow Chart Block 6)

Rather than computing a FOM as for guide/aspect stars, the algorithm simply chooses the brightest N stars (where N=5 or OR specified number) to use as acquisition stars. If less than this minimum number can be found, then take the remedial steps outlined in Section 5.8.

5.7.1 Compute Group Quality Codes

For the star set chosen, the software shall compute a Group Quality Code (GQC). The GQC is the sum of the QCs for the individual stars.

5.7.2 OR/GASSA Selected Stars

The software shall permit constraints on the selection of stars; for example, the OR or the Guide/Aspect Star Selection Algorithm (GASSA) may pre-select one or more stars to be used as acquisition stars. In this case the algorithm shall test the pre-selected set to see if it passes the brightness (Section 5.5) and spatial (Section 5.6) filters. If at least "min_num_acq_stars" out of the pre-selected set pass, the algorithm has successfully chosen a single set of stars to serve as both guide/aspect and acquisition stars. Note that the standard sequence is to test all of the sets of candidate guide/aspect stars as possible acquisition star sets, as shown in Figure 1.

5.8 Depart from Nominal Observation Parameters to Find Acceptable Set of Acquisition Stars (Flow Chart Block 7)

This section specifies what we want the algorithm to do if it doesn't find a set of N stars (where N is "min_num_acq_stars") that pass all the filters above. The software is to attempt each of the fixes below in turn. If one of the fixes works, then the software is required NOT to attempt further fixes.

5.8.1 Use Less Than N Acquisition Stars

Incrementally lower the number of acquisition stars being searched for, until the number reaches "min_num_acq_stars". The algorithm shall be considered successful if at least "min_num_acq_stars" (typically 3, but specified in the SSAPE/ODB) stars can be found.

5.8.2 Try Off Nominal Roll

If the FOM/GQC are unsuitable, then the software should make small changes in the nominal roll angle (±1 degree, ±2 degrees, ... up to the nominal roll limit; as determined from the AXAF characteristics). The algorithm then branches back to (Flow Chart Block 3) and determines a new set of candidate stars. If this "fix" works, then the new set of stars is returned in the MS, along with an indication in the MS that it was necessary to use an off-nominal roll.

5.8.3 Try Alternate FID Lights

If the "fix" in Section 5.8.2 fails, then the software should try using the alternate FID light set. This should first be attempted at the nominal roll, and then at off-nominal rolls as in 5.8.2. If using the alternate FID light set works, then there should be an indication in the MS that the alternate set was used, and the names (numbers) of the alternate FIDS should be listed in the MS. However, only one set of FID lights is allowed per observation interval. That is, the SSA may use the alternate FID light either to find guide/aspect or acquisition stars, but both sets of stars must use the same FID light set.

5.8.4 Accept Higher QCs

If the alternatives in sections 5.8.2 and 5.8.3 fail to find an acceptable set of stars, then the software should branch back to the QC filtering section (5.6.1) and allow stars with the next highest integer value of the ACQQCs. This should continue until an acceptable set of stars is found, or the maximum allowable value of the ACQQC is reached ("acq_c1_code_max", in SSAPE/ODB) for each of the three QCs. A non-zero value of the GQC is then reported in the MS. The use of higher QCs should first be attempted at the nominal roll, then at off-nominal roll, then at nominal roll, alternate FID lights, then at off-nominal roll with alternate FID lights.

5.9 Report Results (Flow Chart Block 8)

The Mission Schedule (sub-element of scheduled OR/ER Data in ODB) should include the stars, fiducial lights, and roll angle which are selected, and the group quality code that results. When the quality code is non-zero, additional information on the outcome of the star selection process may be required as well (TBS).

A Figures

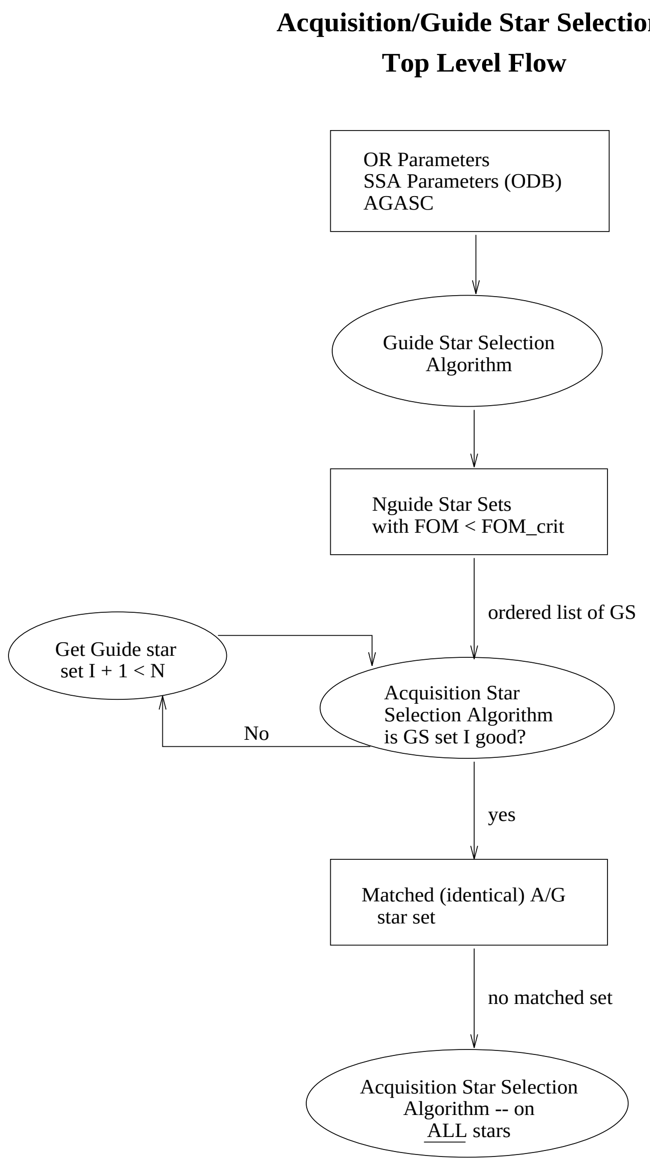

Figure 1: SSA Overview

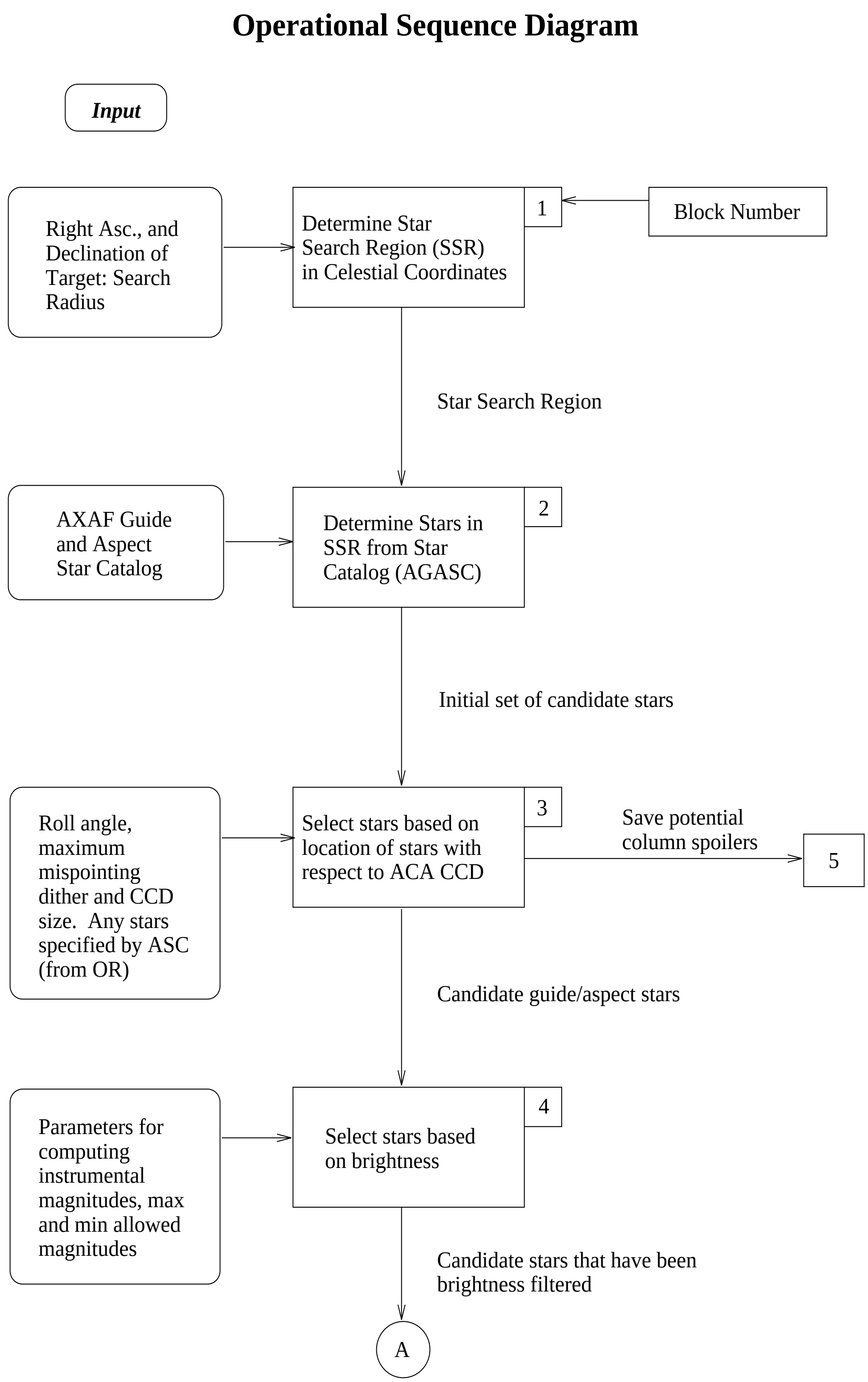

Figure 2: Operational Sequence Diagram, Part 1

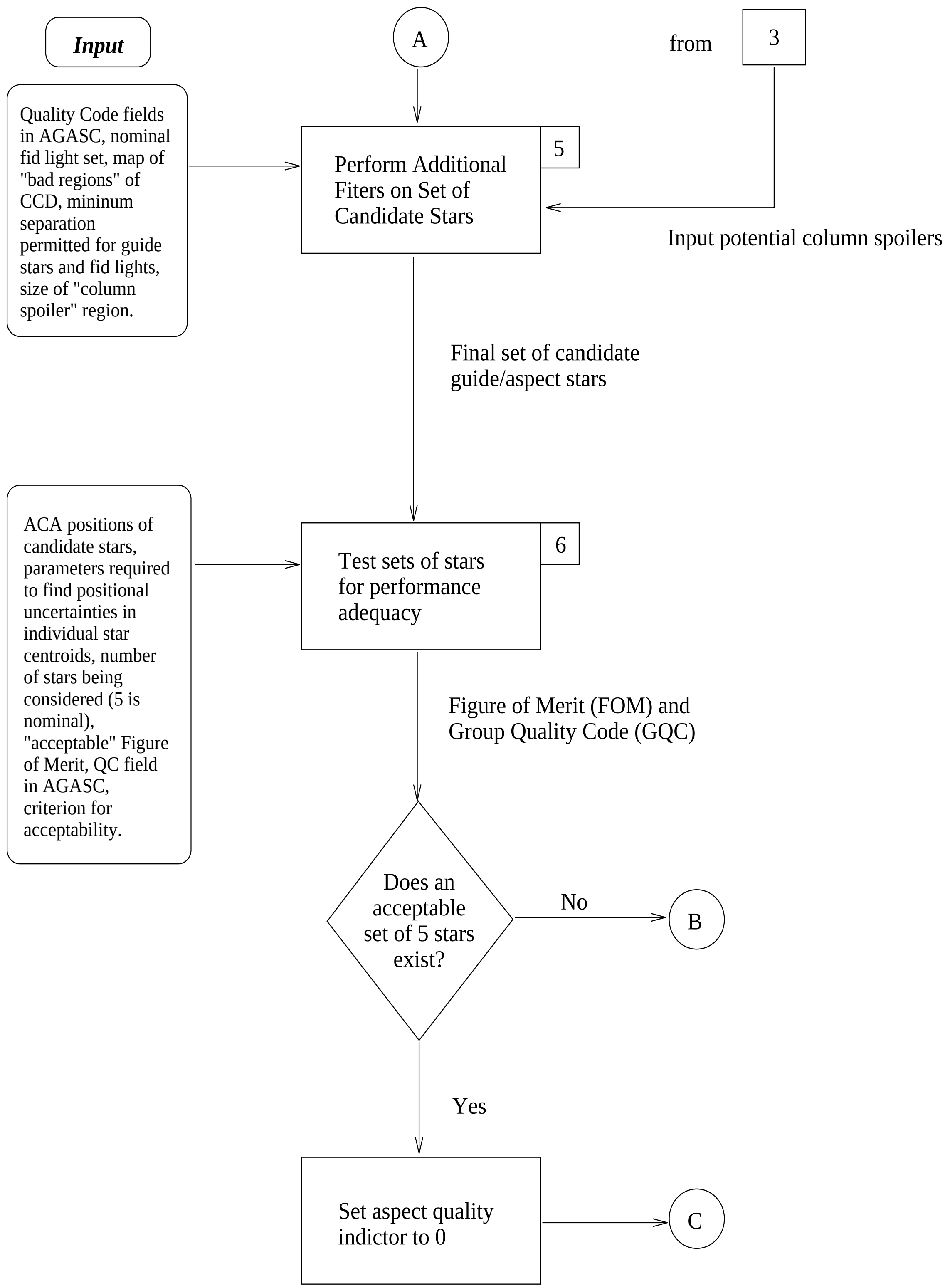

Figure 3: Operational Sequence Diagram, Part 2

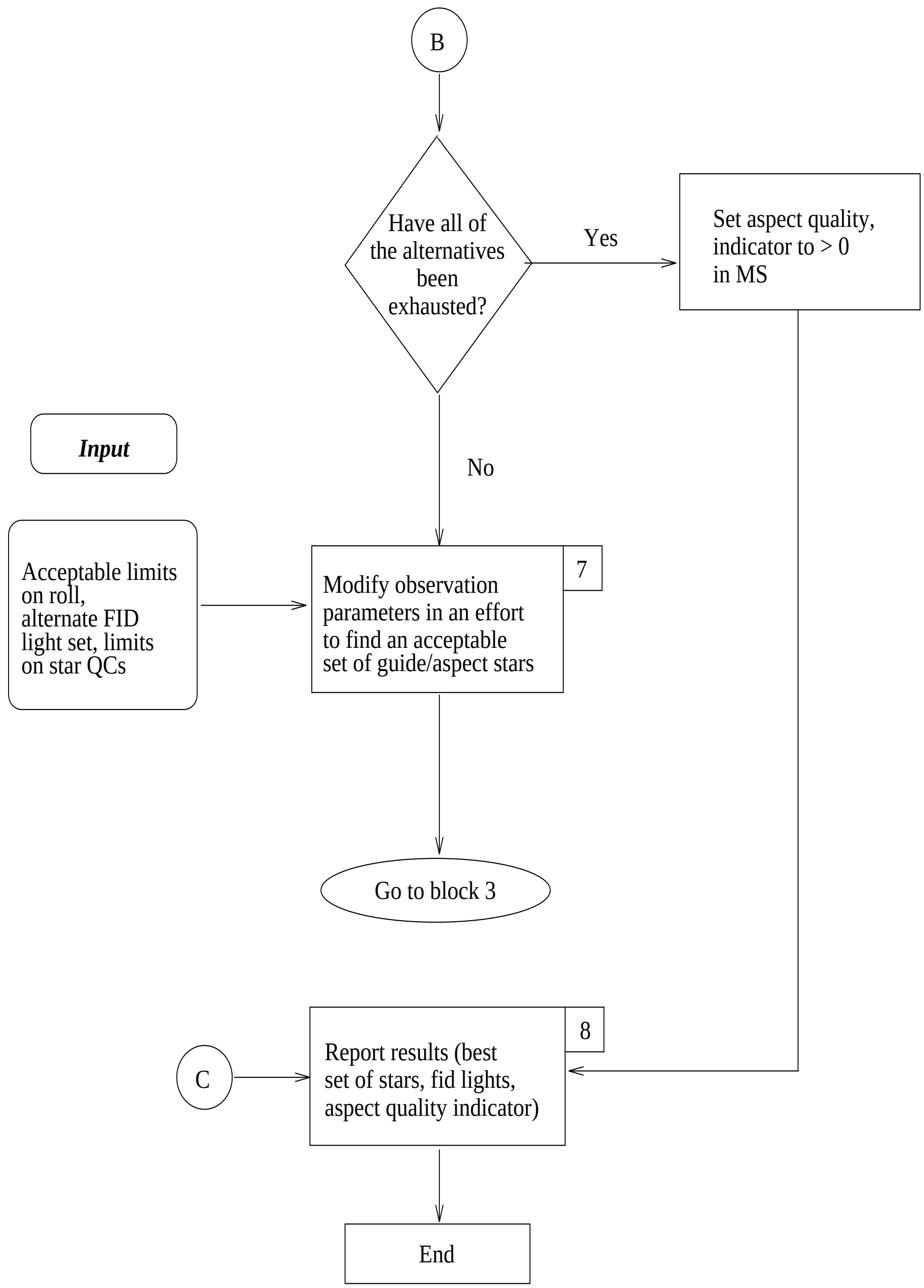

Figure 4: Operational Sequence Diagram, Part 3

B Computing Positional Uncertainty for Single Stars

The Star Selection Algorithm finds a Figure of Merit (FOM) for sets of candidate Guide and Aspect stars (typically there are 5 such stars) according to the formula in Appendix B. This formula is a function of the the uncertainties in the centroid positions of the n (n typically = 5) stars. Here we show how the uncertainties in the centroid positions (the σ_{is}) may be computed.

There are several effects that must be considered:

(a) Contribution due to the brightness of the star. The basic idea here is that the brighter the star is, the better the centroid position. (Of course, systematic uncertainties, discussed below, limit the accuracy to which the centroid may be computed).

Let m_{aca} be the magnitude of the star in Aspect Camera Assembly (ACA) magnitudes. The number of counts accumulated by the ACA from this star is then approximately

$$S = \text{cts\_mag10 x t x } 10^{-0.4(m_{aca}-10)} \qquad \text{counts} \qquad [1]$$

where S = number of counts
t = accumulation time (nominally 1 second)
m_{aca} = instrumental magnitude
cts_mag10 = the number of counts accumulated by the ACA (in one second) for a star of instrumental magnitude 10. Nominally cts-mag10 is 4096.

and

$$\sigma_{mag} = \sigma_{p1} \text{ x} S^{-0.75} + \sigma_{p2} \text{ x } S^{-0.5} \qquad \text{pixels} \qquad [2]$$

where σ_{mag} = uncertainty in stellar centroid position due to instrumental magnitude
σ_{p1} and σ_{p2} are parameters defined in the SSAPE/ODB; current values are:

$$\sigma_{p1} = 16.2 \text{ and } \sigma_{p2} = 0.5$$

(b) Contributions due to location in the telescope FOV.

There is a little additional blurring as you move away from the ACA telescope optical axis. The contribution to the centroiding uncertainty is σ_{off_axis}. This value is computed at the ASC and is input to OFLS as indicated below.

(c) Contributions due to charge-transfer effects in the ACA CCD

If the star in question is located, nominally, near the edges of the CCD, it does not take as many charge transfers to read out the detected photoelectrons. For every charge transfer there is a potential loss of information due to the charge transfer inefficiency (CTI) of the CCD. Therefore, the centroiding process is more accurate for stars located near the edge of the CCD and less accurate for stars near the center.

The charge-transfer effect depends on the magnitude of the star being observed. The factor (call it, say, transfer_blur_factor) is computed by the ASC. Its effect on the σ_i is given below.

(d) Finally we must account for other systematic uncertainties which limit the ultimate accuracy of the star centroiding process. We choose to do this by assigning a residual systematic uncertainty to each pixel in the ACA CCD (call it σ_{CCD}). These uncertainties arise from such things as position calibration residuals, non-uniformity of the CCD responsivity and dark current. The entries in the 1024 x 1024 uncertainty array will be computed by the ASC and stored in the SSAPE/OBD.

(e) Averaging the CCD effects

Uncertainty contributions (b), (c) and (d) depend on the nominal location of the star in CCD chip. Since the star wanders around the chip due to initial mispointing, jitter and programmed dither, it is incorrect to use a value based on a precise location in the ACA CCD. Rather we must do an average over the CCD pixels where the star might fall during an observation. The size of this region is approximately

$(d_1 + \delta)$ x $(d_2 + \delta)$ $pixel^2$ where d_1 and d_2 are the dither amplitudes in the (y,z) direction and δ is the pointing uncertainty due to initial mispointing and attitude jitter.

To average the effects in (b), (c) and (d), the OFLS shall take the values of the effects for each pixel in the region and average them (all pixels equally weighted, TBR).

(f) Computation of σ_i

The formula for the uncertainty in the centroid of a single star is, therefore:

$\sigma_i = \sigma_{mag}$ x $< transfer\_blur\_factor > + < \sigma_{off\_axis} > + < \sigma_{CCD} >$

where <> indicates the appropriate average as described in (e) above.

(g) Implementation at the OFLS

The OFLS must write software to compute the σ_i. The ASC will supply the required parameters to make the computations. These are:

1. The parameters needed to compute σ_{mag}, i.e., σ_{p1}, σ_{p2}, and t. m_{aca} will be available from the Star Catalog, either directly or by computation from the listed magnitudes.
2. A multiplicative array of dimension 1024 x 1024 giving the transfer_blur_factor for every CCD pixel.
3. An additive array of dimension 1024 x 1024 giving the effects of telescope off-axis blurring and the remaining CCD uncertainties (i.e., the sum of σ_{off_axis} and σ_{CCD}).

4. The pointing uncertainty due to initial mispointing and attitude jitter. The OFLS must find the dither magnitude(s) in the Observation Request.

C Figure of Merit (FOM) Formula

Let σ_i be the one-dimensional uncertainty in the position of star i. We simplify this formula somewhat by insisting that the $\sigma_{yi} = \sigma_{zi}$, (*i.e.*, the uncertainties for a given star are the same in both the y and z directions) although the σ_i need not be the same as σ_j. The resulting equation for the figure of merit is

$$\sigma_x^2 = \frac{2}{\sum_i 1/\sigma_i^2} + \frac{\bar{\xi^2} + \bar{\eta^2}}{\sum_i \frac{(\xi_i - \bar{\xi})^2 + (\eta_i - \bar{\eta})^2}{\sigma_i^2}}$$

where (ξ_i, η_i) is the position of star i in CCD coordinates. Here the $\bar{\xi}$ and $\bar{\eta}$ are the weighted means (weighted by the uncertainty σ_i^2)

$$\bar{\xi} = \sum_i \frac{\xi_i}{s_i^2}$$

$$\bar{\eta} = \sum_i \frac{\eta_i}{s_i^2}$$

and where $s_i^2 = \sigma_i^2 \sum_j (1/\sigma_j^2)$.

This formula may be somewhat simplified:

$$\sigma_x^2 = \frac{1}{\sum_i (1/\sigma_i^2)} \left\{ 2 + \frac{\bar{\xi^2} + \bar{\eta^2}}{((\bar{\xi^2} + \bar{\eta^2}) - (\bar{\xi}^2 + \bar{\eta}^2))} \right\}$$

where the $\bar{\xi}$ and $\bar{\eta}$ are as defined above and the $\bar{\xi^2}$ and $\bar{\eta^2}$ are defined similarly, *i.e.*,

$$\bar{\xi^2} = \sum_i \frac{\xi_i^2}{s_i^2}$$

$$\bar{\eta^2} = \sum_i \frac{\eta_i^2}{s_i^2}$$

D Star Selection Algorithm Parameter Element, Operations Data Base (SSAPE/ODB)

This appendix contains the specification for the SSA Parameters data element of the AXAF Operations Data Base (ODB), and constitutes an update of the preliminary specification contained in TRW DR OP19, ODB Users' Guide, dated 15 May 1995. This data element specification is provided for reference in interpreting the SSA specification contained in the main body of this document.

The SSA Parameters data element contains a file of parameters used with the star selection algorithm in the OFLS to select acquisition stars and guide/aspect stars from the AXAF-I Star Catalog to support AXAF on-orbit operations. The parameter file contains the following information:

- ACA and other PCAD-related parameters, used in defining star search and selection regions within the overall star field as represented in the AXAF Star Catalog
- Star brightness prediction and related star selection parameters
- Star filtering parameters supporting image position prediction on the ACA detector, and screening of candidate stars based on predicted detector position coordinates
- Candidate-star-set evaluation and selection parameters
- Additional parameters controlling the selection of a single set of stars that satisfy both guide/aspect star and acquisition star criteria.

The SSA Parameters data element is provided as a flat file, consisting of the following fields:

- Search-radius about pointing direction, for initial star identification

search_radius	Real	Radius of search region (deg), centered at observation RA and dec, within which to read initial set of stars from star catalog

- ACA reference aperture

max_aca_row	Int	Maximum ACA pixel row number
max_aca_col	Int	Maximum ACA pixel column number
min_aca_row	Int	Minimum ACA pixel row number
min_aca_col	Int	Minimum ACA pixel column number
Pixel_size	Real	ACA pixel width (arcsec)

- Pointing error bounds

max_point_error	Real	Maximum pointing error during attitude hold (arcsec)
max_dither	Real	Maximum dither amplitude (arcsec)
max_slew_error	Real	Maximum pointing error at end of slew (arcsec)

- Star selection brightness thresholds, used in selecting candidate guide/aspect and acquisition stars from among those in the ACA reference field of view. (Thresholds are specified for the apparent brightness as seen by the ACA, considering the spectral response characteristics of the ACA detector.)

g_max_mag	Real	Maximum instrument magnitude, for guide/aspect stars
g_min_mag	Real	Minimum instrument magnitude, for guide/aspect stars
a_max_mag	Real	Maximum instrument magnitude, for acquisition stars
a_min_mag	Real	Minimum instrument magnitude, for acquisition stars

- Star brightness conversion coefficients (11 coefficients); used to estimate the apparent brightness of a star as seen by the ACA detector (= MAG_I)

aca_mag_O0	Real	ACA magnitude 0th order offset
aca_mag_01	Real	ACA magnitude scale factor coefficient
aca_mag_O1_c1	Real	ACA magnitude 1st order coefficient of color 1 (c1, in AXAF Star Catalog)
aca_mag_O1_c2	Real	ACA magnitude 1st order coefficient of color 2 (c2)
aca_mag_O1_c3	Real	ACA magnitude 1st order coefficient of color 3 (c3)
aca_mag_01_c12	Real	ACA magnitude 1st order coefficient, c1-c2
aca_mag_01_c23	Real	ACA magnitude 1st order coefficient, c2-c3
aca_mag_01_c13	Real	ACA magnitude 1st order coefficient, c1-c3
aca_mag_02_c12	Real	ACA magnitude 2nd order coefficient, (c1-c2)**2
aca_mag_02_c23	Real	ACA magnitude 2nd order coefficient, (c2-c3)**2
aca_mag_02_c13	Real	ACA magnitude 2nd order coefficient, (c1-c3)**2

- Star magnitude conversion method flag; specifies whether to compute apparent star brightness as seen by the ACA (MAG_I, instrument magnitude) from color intensity (c1-c3) star data records in the AXAF Star Catalog, or read instrument magnitude directly from star data records

star_mag_conv_flag	Int	1=compute, 0=read directly

- ACA detector scale factors

n_param_trans	Int	No. of parameters for star sky-coordinates- to-ACA-detector-coordinates transform
r_sky_to_aca[0]	Real	sky-to-aca offset vector,x (mm)
r_sky_to_aca[1]	Real	sky-to-aca offset vector,y (mm)
r_sky_to_aca[2]	Real	sky-to-aca offset vector, z (mm)
sky_to_aca_scaling	Real	sky-to-aca scaling factor (mm/rad)
U_22	Real	component of U matrix (dimensionless)
U_23	Real	component of U matrix (dimensionless)
U_32	Real	component of U matrix (dimensionless)
U_33	Real	component of U matrix (dimensionless)
V_222	Real	component of V matrix (mm/(rad^2))
V_223	Real	component of V matrix (mm/(rad^2))
V_233	Real	component of V matrix (mm/(rad^2))
V_322	Real	component of V matrix (mm/(rad^2))
V_323	Real	component of V matrix (mm/(rad^2))
V_333	Real	component of V matrix (mm/(rad^2))
si_to_aca_scaling	Real	SI-to-aca scaling factor (dimensionless)

- ACA detector centroid position uncertainty coefficients, for position uncertainty calculations from star magnitude and centroid coordinates

n_params_epos	Int	No. of parameters for computation of star positional uncertainty (sigma)
count_threshold	Real	Flux level above which sigma doesn't improve
sigma_p1	Real	First coefficient of positional uncertainty eqn
sigma_p2	Real	Second coefficient of positional uncertainty eqn
max_off_axis_sigma	Real	Max % star sigma increase from off-axis effect
par_signal_loss	Real	Signal loss from parallel (Z) readout transfers
ser_signal_loss	Real	Signal loss from serial (Y) readout transfers

- Fid light keepout distance (angular radius); used to specify the minimum distance between an acceptable star image and a fidlight image on the ACA detector, and apparent FID magnitude

fid_spoil_region	Int	Keepout distance, in pixels (stars within ± X pixels of fids are spoiled)
fid_aca_mag	Real	Apparent magnitude of FID lights in ACA

- Fid light selection index that selects candidate fiducial lights

i_fid_select	Int	Key to fid light look-up table

- Keepout parameters for ACA detector column spoilers check; the allowable upper limit on spoiler star brightness, plus other parameters

rad_mag_diff_limit	Real	This many mags brighter to be radial spoilers
col_mag_diff_limit_g	Real	This many mags brighter to be column spoilers for guide/aspect stars
col_mag_diff_limit_a	Real	This many mags brighter to be column spoilers for acquisition stars
exc_mag_diff_limit	Real	Within this many mags to be exclusion box spoofer
col_spoil_col_limit	Int	Within this many columns to be column spoiler

- ACA detector centroid position uncertainty index array, and scale factors, to be rss combined, three 1024^2 arrays

aca_err_array_coef	Real	Coefficient for aca error array
aca_t_err_array_coef	Real	Coefficient for additive aca error array
aca_err_array	Real	File name for aca error array
aca_t_err_array,	Real	File name for additive aca error array

- ACA detector bad-region map (details TBD)

- Limit on number of stars to consider as candidate guide/aspect stars

max_filtered_list_len	Int	Maximum number of stars to accept in the filtered star list

- Expanded-search parameter secondary limits; used in an expanded search for aspect and acquisition stars when the primary search and selection criteria fail to converge on a set of stars meeting default criteria.

min_acceptable_fom	Real	FOM less than this meet error tree requirements

- Acceptable ranges on quality codes; six pairs of integers indicating high and low limits for guide/acq star quality codes

acq_c1_code_min	Int	Min allowable acq c1 code
acq_c1_code_max	Int	Max allowable acq c1 code
acq_c2_code_min	Int	Min allowable qcq c2 code
acq_c2_code_max	Int	Max allowable acq c2 code
acq_c3_code_min	Int	Min allowable acq c3 code
acq_c3_code_max	Int	Max allowable acq c3 code
guide_c1_code_min	Int	Min allowable guide c1 code
guide_c1_code_max	Int	Max allowable guide c1 code
guide_c2_code_min	Int	Min allowable guide c2 code
guide_c2_code_max	Int	Max allowable guide c2 code
guide_c3_code_min	Int	Min allowable guide c3 code
guide_c3_code_max	Int	Max allowable guide c3 code

- Number pertaining to selection of acquisition stars

FOM_list_len	Int	Number of FOMs to retain, in ordered list of guide/aspect star candidate sets
min_num_acq_stars	Int	Minimum number of acquisition stars required for successful star search

- Factors for slew errors due to IRU scale uncertainties

slew_error_m1	real	coefficient for slew error, slew between 0 and 30 degrees
slew_error_m2	real	coefficient for slew error, slew between 30 and 60 degrees
slew_error_m3	real	coefficient for slew error, slew between 60 and 90 degrees
slew_error_m4	real	coefficient for slew error, slew between 90 and 120 degrees
slew_error_m5	real	coefficient for slew error, slew between 120 and 150 degrees
slew_error_m6	real	coefficient for slew error, slew between 150 and 180 degrees
slew_error_b1	real	intercept for slew error, slew between 0 and 30 degrees
slew_error_b2	real	intercept for slew error, slew between 30 and 60 degrees
slew_error_b3	real	intercept for slew error, slew between 60 and 90 degrees
slew_error_b4	real	intercept for slew error, slew between 90 and 120 degrees
slew_error_b5	real	intercept for slew error, slew between 120 and 150 degrees
slew_error_b6	real	intercept for slew error, slew between 150 and 180 degrees
slew_error_t0	real	slew angle rand limits for error equations
slew_error_t1	real	slew angle rand limits for error equations
slew_error_t2	real	slew angle rand limits for error equations
slew_error_t3	real	slew angle rand limits for error equations
slew_error_t4	real	slew angle rand limits for error equations
slew_error_t5	real	slew angle rand limits for error equations
slew_error_t6	real	slew angle rand limits for error equations